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Part I. Oxoammonium Salts as Selective Oxidants
Part II. Conformational Studies of Saturated
Heterocycles: The Importance of Electrostatic
Interactions

Kyle M. Lambert

University of Connecticut - Storrs, kyle.lambert@uconn.edu

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Part I. Oxoammonium Salts as Selective Oxidants

Part II. Conformational Studies of Saturated Heterocycles: The Importance of Electrostatic Interactions

Kyle M. Lambert, Ph.D.

University of Connecticut, 2017

Novel oxidation methods utilizing oxoammonium salts have been developed and are discussed in the first portion of this work. By employing a stoichiometric amount of a commercially available oxoammonium salt, known as “Bobbitt’s salt,” a facile and efficient procedure for the oxidation of primary amines to nitriles has been realized. This methodology was further adapted into an efficient, scalable catalytic process. The use of Oxone[®] as an inexpensive, environmentally benign terminal oxidant allows for the *in situ* production of an oxoammonium salt, the primary oxidant, from a small quantity of 4-acetamido-2,2,6,6-tetramethylpiperidine-N-oxyl (4-acetamidoTEMPO or ACT), a nitroxide catalyst, accomplishing the oxidation of primary amines to nitriles. Mechanistic aspects and scope of the oxidations are fully described. A novel oxoammonium salt oxidant has been developed by the electronic modification of “Bobbitt’s salt” and the kinetics of the oxidation of alcohol substrates by these salts has been studied.

The second portion of this work involves evaluation of the conformational equilibria found within a variety saturated heterocycles and small molecules with an aim to elucidate the origin of conformational effects often observed in such systems. Particular attention is drawn to the role of electrostatic interactions in determining the conformational preferences within small molecules. Free-energy differences have been experimentally determined for a series of anancomeric 2,2-diaryl-1,3-dioxanes, 5-phenyl-1,3- dioxanes, 2-substituted-1,3-dioxanes, and substituted cyclohexane systems. Computational modeling, X-ray crystallography, and two-dimensional nuclear magnetic resonance studies were used to evaluate the experimental results. Intramolecular electrostatic interactions have been found to engender

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fascinating conformational phenomena, and in some cases, to a greater extent than what was previously understood.

Part I. Oxoammonium Salts as Selective Oxidants

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Kyle M. Lambert

B.S. – Chemistry, University of New Haven, **2012**

B.S. – Forensic Science, University of New Haven, **2012**

A Dissertation

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Doctor of Philosophy

at the

University of Connecticut

2017

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2017

APPROVAL PAGE

Doctor of Philosophy Dissertation

Part I. Oxoammonium Salts as Selective Oxidants

Part II. Conformational Studies of Saturated Heterocycles: The Importance of Electrostatic Interactions

Presented by

Kyle Michael Lambert, B.S.

Major Advisor _____
William F. Bailey

Associate Advisor _____
James M. Bobbitt

Associate Advisor _____
Mark W. Peczu

Associate Advisor _____
Michael B. Smith

University of Connecticut
2017

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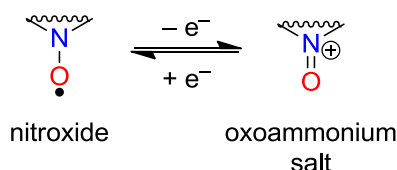
PART I.

OXOAMMONIUM SALTS AS SELECTIVE OXIDANTS

CHAPTER I. INTRODUCTION

1.1 Historical Aspects of Oxoammonium Salt Oxidants

Oxidative transformations are an important part of modern organic chemistry, and amongst the plethora of reagents available for oxidation chemistry, oxoammonium salts¹ offer pronounced selectivity and versatility superior to that of other oxidizing reagents. Oxoammonium salts can be synthesized through a one-electron oxidation of stable *N*-oxyl free radicals known as nitroxides (Scheme 1-1).



Scheme 1-1

The first stable *N*-oxyl free radical to appear in the literature was reported by Edmond Frémy in 1845 when he synthesized “sulfazidate de potasse”, which is now known as potassium nitrosodisulfonate or “Frémy’s salt” (Figure 1-1).² Frémy realized the potential of this new salt as a powerful oxidant, and it is still employed today in the synthesis of quinones from phenols and anilines, the oxidation of benzylic alcohols to aldehydes or ketones, and as a standard in electronic spin resonance studies.³

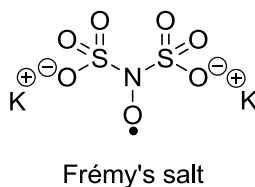
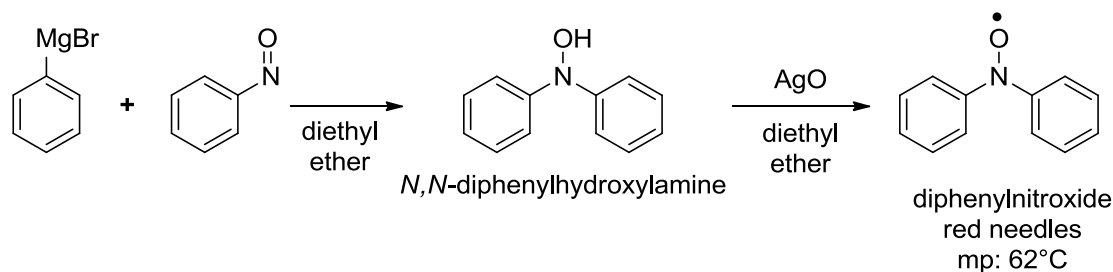


Figure 1-1

The first stable organic-based *N*-oxyl radical was synthesized in 1914, over half a century after Frémy’s salt, when Wieland and Offenbächer reacted phenylmagnesium bromide with nitrosobenzene to afford *N,N*-diphenylhydroxylamine; which upon oxidation by silver (I) oxide yielded diphenylnitroxide

(Scheme 1-2).⁴ This nitroxide, while isolatable as a red crystalline solid, was not particularly stable and decomposed within a few hours upon exposure to air, as noted by Wieland and Offenbächer. The structure of this nitroxide was not correctly assigned at the time of its discovery, however, it was clearly noted by the authors that the compound was indeed a radical.



Scheme 1-2

The chemical structure of *N*-oxyl radicals and the factors that contribute toward the surprising stability of the persistent radical would remain unclear until the late 1950's, when the first of the 2,2,6,6-tetramethylpiperidine-based nitroxides were prepared and characterized.⁵ The absence of an α -hydrogen to the *N*-oxyl radical and the bulky α -methyl groups help to stabilize the radical in this series of nitroxides (Figure 1-2).

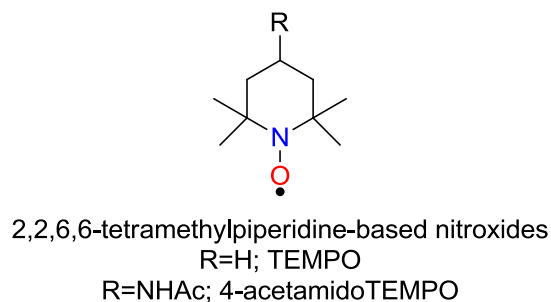
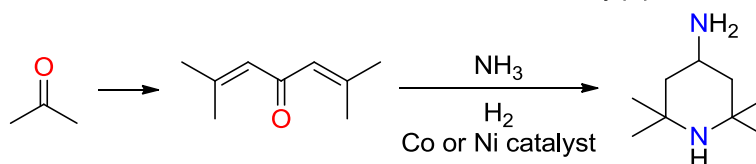


Figure 1-2

The most-well known of these nitroxides is 2,2,6,6-tetramethylpiperidine-1-oxyl (TEMPO) as shown in Figure 1-2, when R=H. While a variety of nitroxide derivatives have been and continue to be synthesized⁶, many are derivatives of the TEMPO parent structure with the C4 position most likely to be substituted. One of the most affordable nitroxides to produce is 4-acetamido-2,2,6,6-tetramethylpiperidine-1-oxyl (4-acetamidoTEMPO) (R=4-NHAc, Figure 1-2) as it is derived from 4-

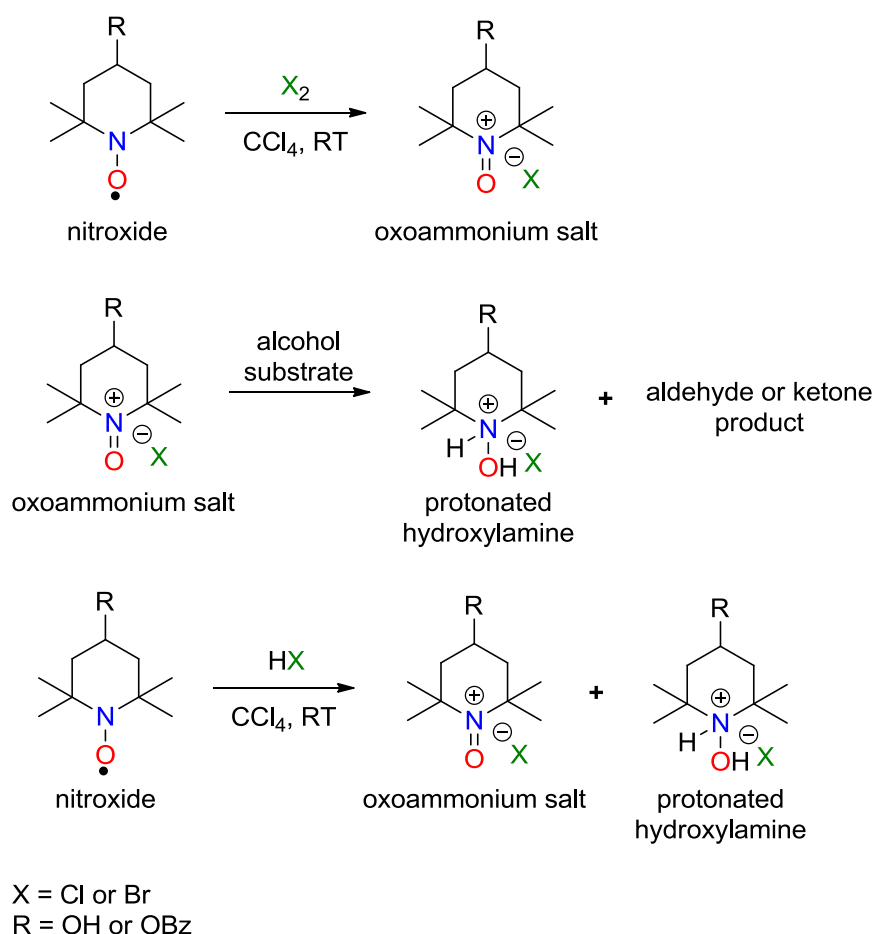
amino-2,2,6,6-tetramethylpiperidine, which is readily available as it is used as a component of commercial detergents and is produced commercially from the high-pressure condensation of acetone and ammonia followed by reduction over a hydrogenation catalyst (Scheme 1-3).⁷ The 4-acetamidoTEMPO derivative was the nitroxide of choice for a portion of this work.

Commercialized route to 4-amino-2,2,6,6-tetramethylpiperidine:



Scheme 1-3

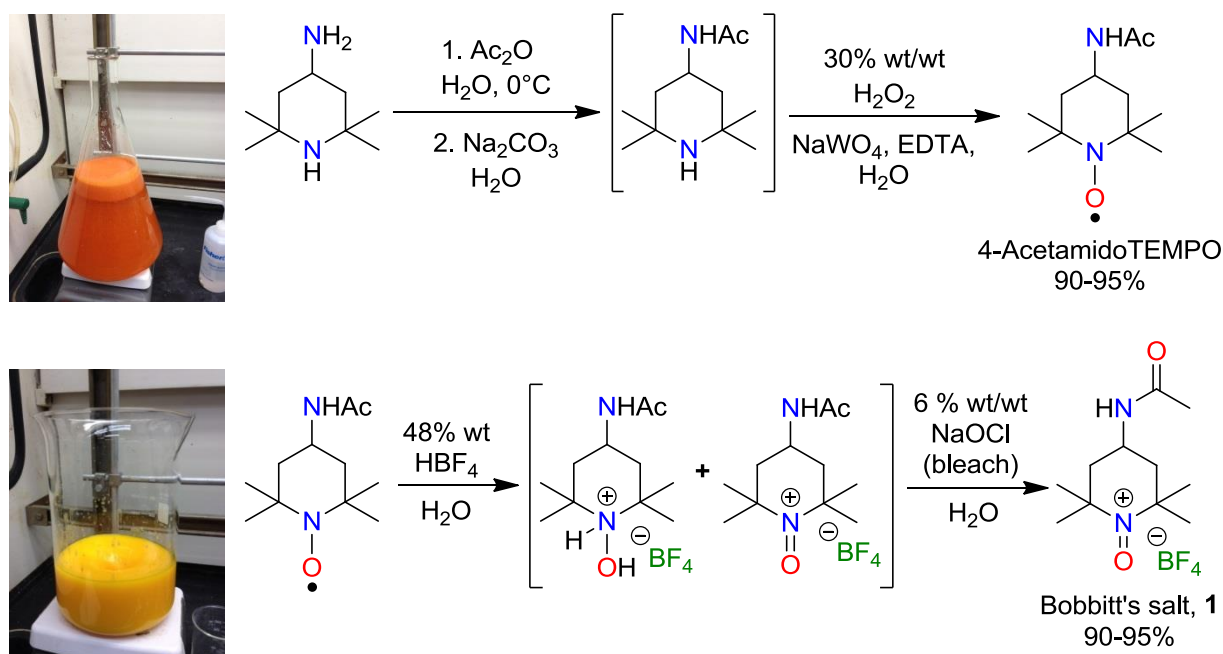
Golubev and co-workers were the first to realize that the unique redox properties of nitroxides would allow for their use as oxidants in organic synthesis.⁸ In 1965, Golubev reported that when 4-hydroxypiperidine-1-oxyl and 4-benzoyloxypiperidine-1-oxyl were treated with bromine or chlorine, brightly colored diamagnetic salts formed in near quantitative yield (Scheme 1-4).⁸ While, oxoammonium salts were synthesized much earlier in 1919 and 1921 by Meyer and co-workers⁹, the chemical structures as well as the reactivity of the synthesized derivatives were not well understood at the time, and Golubev et al. were the first to correctly identify and characterize oxoammonium salts. One of the seminal findings of this report⁸ (Scheme 1-4) was that oxoammonium salts oxidize primary and secondary alcohols to the corresponding aldehydes and ketones respectively and that in the process the oxoammonium salt was reduced to its hydroxylamine analogue. Another finding was that when nitroxides were treated with hydrohalic acids such as hydrochloric and hydrobromic acid, they give rise to an equivalent of oxoammonium salt and an equivalent of a hydroxylamine salt in a disproportionation process. These discoveries would catalyze the advancement of oxoammonium salts as effective oxidants.^{10,11}



Scheme 1-4

While Golubev⁸ and Endo¹¹ prepared oxoammonium salts with chloride and bromide anions, a variety of other anions have been used such as NO₃,¹² ClO₄,¹³ Br₃,^{14,15} PF₆,¹⁵ SbF₆,¹⁵ and BF₄.¹³ The reactivity and properties of oxoammonium salts appear to be slightly altered based on the anion present. The halide series of anions, chloride, bromide, and tribromide are hygroscopic, which complicates oxidations that require anhydrous conditions, and can result in halogenation of the substrate¹⁶ when these oxoammonium salts are generated in situ from the corresponding nitroxides. While oxoammonium salts containing the perchlorate anion have been employed in a variety of oxidations, the use of the perchlorate derivative is highly discouraged as it has the ability to detonate.¹⁷ The tetrafluoroborate counterion is preferable in some regards as it results in high-melting, highly crystalline, yellow oxoammonium salts that are remarkably bench stable, exhibit good reactivity, and have desirable solubility properties.^{13,17} The

oxoammonium salts of TEMPO are among the most well-known as TEMPO is a readily available nitroxide. As described above, 4-acetamidoTEMPO is substantially less expensive to produce as compared to TEMPO itself, and as a result, its tetrafluoroborate salt, 4-acetamido-2,2,6,6-tetramethyl-1-oxo-piperidinium tetrafluoroborate (Bobbitt's salt, **1**) has been used extensively. While both 4-acetamidoTEMPO and **1** are commercially available, each can be easily prepared in multi-molar quantities at substantially less cost (ca. 1 U.S. dollar per gram) from known procedures (Scheme 1-5).^{13,18} Additionally, the acetamido group imparts favorable solubility qualities to this oxoammonium salt that greatly simplifies its use and isolation from oxidation products. For these reasons, **1** was the oxoammonium salt of choice for this work.



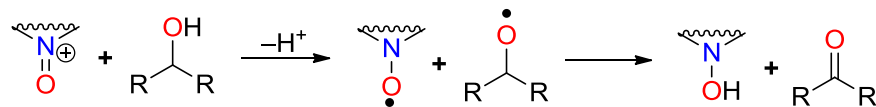
Scheme 1-5

1.2 Mechanistic Aspects of Oxoammonium Salt Oxidants

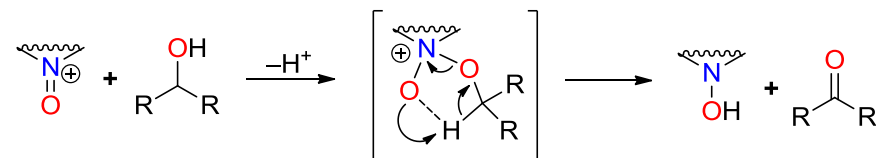
Much of the selectivity observed for oxidations involving oxoammonium salt oxidants originates from the unique property that the oxidations occur via a hydride transfer from the substrate to the oxoammonium salt. In the original report⁸ of the oxidation of alcohols to aldehydes or ketones, it was suggested that the reaction may proceed via one of two mechanisms, a radical or an intramolecular cyclic

mechanism where a proton is abstracted from the substrate by the oxoammonium salt (Scheme 1-6). While these two mechanisms were initially proposed, they are no longer viewed as the generally accepted mechanism for the oxidation.

Proposed radical process:



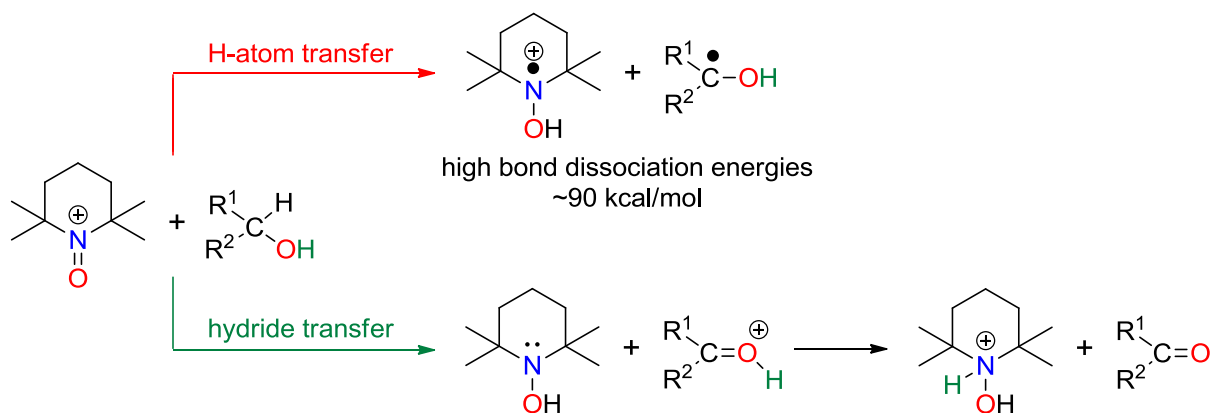
Proposed cyclic process:



Scheme 1-6

Further insight into the mechanism of the oxidation of alcohols by oxoammonium salts was provided by Golubev and co-workers¹⁹ when they measured the kinetics of the process. It was noted that secondary alcohols were oxidized, in general, faster than primary alcohols, and the rate of oxidation was pH and concentration dependent. This led to the proposal that the oxoammonium cation likely removes a hydride from the alcohol substrate in the rate-limiting step of a heterolytic process. Another proposed pathway would involve a homolytic process where the rate-limiting step was the formation of radical intermediates such as the nitroxide radical, however this was found not to be the case as the oxidation was independent of O_2 concentration.¹⁹ It is now generally accepted that the oxidation does indeed proceed via a hydride transfer from the substrate to the oxoammonium cation.^{20,21} Bailey, Bobbitt, and Wiberg computationally investigated the mechanism of oxoammonium salt oxidations,²⁰ and found that under acidic conditions a hydride transfer process has a much lower activation energy (~ 28 kcal/mol for isopropanol and ~ 43 kcal/mol for methanol) as compared to the high C-H bond dissociation energies (~ 90 kcal/mol) of the alcohol substrates required for a radical process (Scheme 1-7). Invoking a hydride transfer mechanism clearly explains the experimental observations¹⁰ that secondary alcohols are oxidized

at a faster rate than primary alcohols, and benzylic or aliphatic alcohols are oxidized at a faster rate than aliphatic alcohols, as the positively charged transition state is further stabilized.



Scheme 1-7

Another aspect that has been investigated is where the hydride ends up on the oxoammonium salt, the nitrogen (path a Figure 1-3) or the oxygen (path b Figure 1-3). Additionally, Figure 1-3 depicts the computed space-fill model of the oxoammonium salt viewed from the side and from the top of the molecule.²² It is clearly shown that the nitrogen atom of the oxoammonium cation is highly inaccessible and the four adjacent methyl groups help to shield it from nucleophilic attack. In fact, when Grignard reagents,^{23,24} tri-substituted alkenes,²⁵ enols²⁶ and enolates²⁷ are added to solutions containing a TEMPO-based oxoammonium salt, the nucleophile adds to the oxygen, and no addition to the nitrogen is observed. Given the spatial constraints of the oxoammonium cation, the experimental results seem to suggest the oxygen atom is much more accessible, whereas the nitrogen atom is much too hindered to be attacked by nucleophiles other than perhaps a hydride or to accept a proton in its reduced hydroxyl amine form.

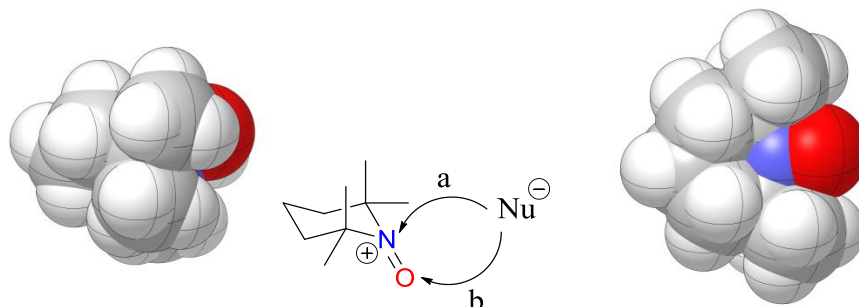
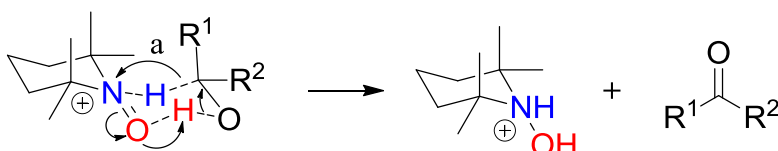


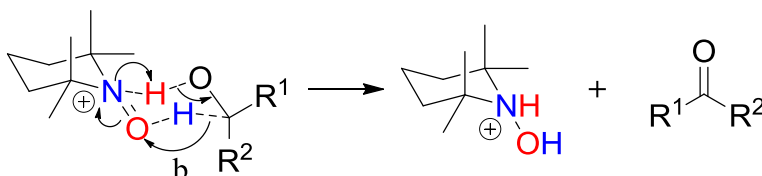
Figure 1-3

During the oxidation of alcohols, the delivery of the hydride can proceed in two possible ways: as a step-wise process where the hydride is removed resulting in a protonated aldehyde or ketone, which is then further deprotonated by the resulting hydroxylamine²⁰ or as a concerted process via a six-membered transition state as shown in Scheme 1-8.

hydride delivered to the nitrogen:



hydride delivered to the oxygen:



$\text{H}^- = \text{blue}$

$\text{H}^+ = \text{red}$

Scheme 1-8

Pathway A as shown in Scheme 1-8, depicts a six-membered transition state, where the hydride is delivered to the nitrogen. A potentially destabilizing steric interaction may exist between the α -methyl groups and the substituents on the alcohol (R^1 and R^2) and there is a mismatch of the dipoles in the transition state of pathway a. Pathway B also depicts a six-membered transition state, but the hydride is delivered to the oxygen. This transition state is viewed more favorably as the substituents on the alcohol (R^1 and R^2) should have minimal interaction with the bulky methyl groups, the alcohol substrate and the oxoammonium cation are arranged as so that the dipoles are aligned to help stabilize the transition state, and delivery of the hydride to the oxygen is consistent with the experimental observation that nucleophiles add to the oxygen. It has yet to be shown on which atom of the oxoammonium cation accepts the hydride during oxidations in near-neutral or acidic conditions.

Oxidations that proceed under basic conditions appear to be much more involved in regard to mechanism. Some of the first oxoammonium salt oxidations of substrates other than simple alcohols^{28,29} employed the TEMPO nitroxide, which was oxidized *in situ* through an electrochemical process or the use of a secondary chemical oxidant. Semmelhack and coworkers were the first to develop a methodology that proceeded under basic conditions when they reported a electrochemical method employing a catalytic quantity of TEMPO and 2,6-lutidine as an external base to oxidize a variety of alcohols (Chart 1-1).²⁹ It was reported that primary alcohols were oxidized preferentially over secondary alcohols, which is in contrast to what was observed under acidic conditions⁸ where secondary alcohols were oxidized over primary alcohols. This led Semmelhack to investigate the mechanism of oxidation of alcohols by oxoammonium salts under basic conditions.²⁴ Four possibilities (Scheme 1-9) were considered: (a) an electron abstraction and proton loss from the alcohol to give a hydroxyl radical and the nitroxide, which would quickly react to furnish the aldehyde and a hydroxylamine due to the instability of the hydroxyl radical (b) direct hydride abstraction from the hydroxyl-bearing carbon of the alcohol to give the hydroxylamine and oxonium ion, which would be deprotonated by the base (c) formation of a reactive adduct by nucleophilic attack on the nitrogen of the oxoammonium salt and subsequent collapse of the intermediate via hydrogen abstraction from the substrate to furnish the hydroxylamine and the aldehyde product (d) formation of a reactive adduct by nucleophilic attack on the oxygen of the oxoammonium salt subsequent collapse of the intermediate via hydrogen abstraction from the substrate to furnish the hydroxylamine and the aldehyde product.

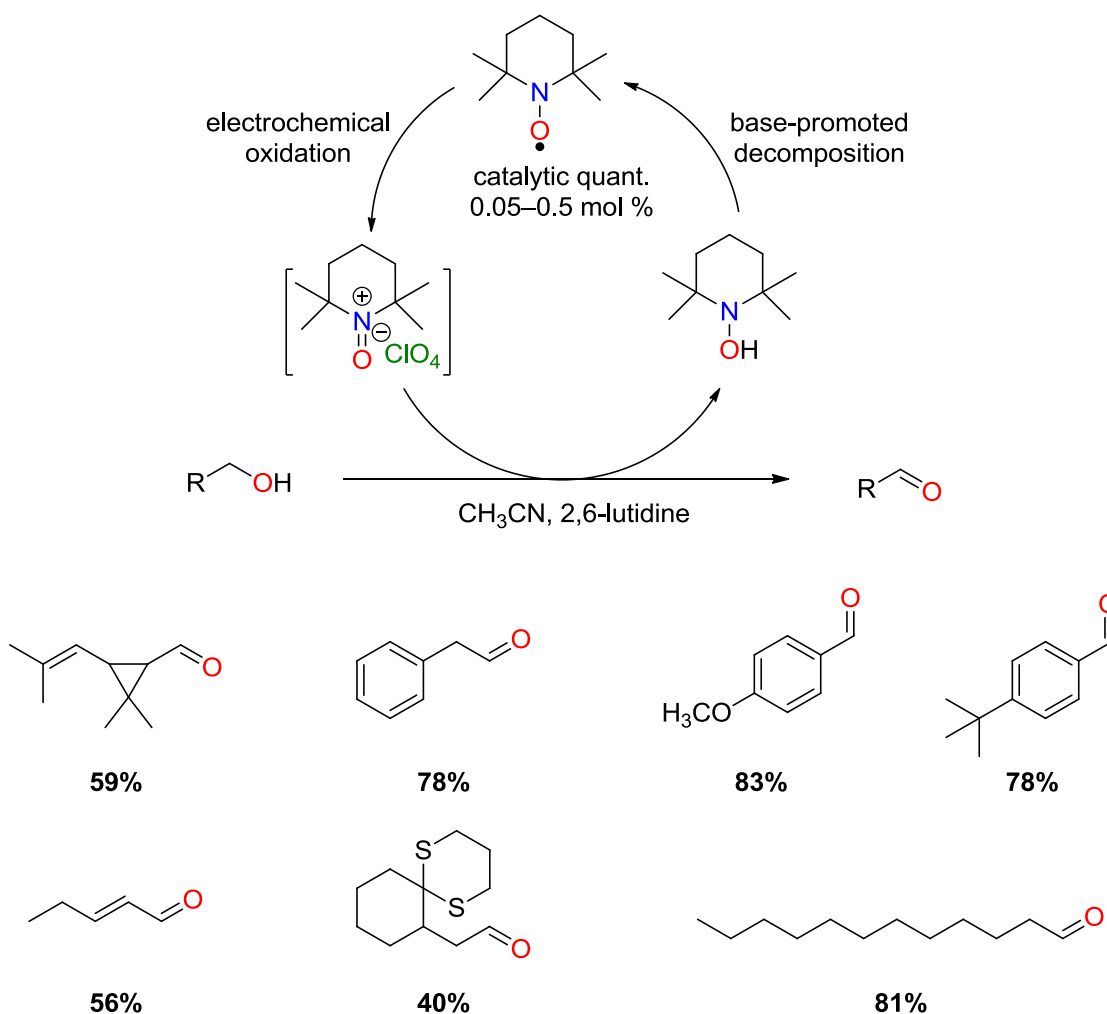
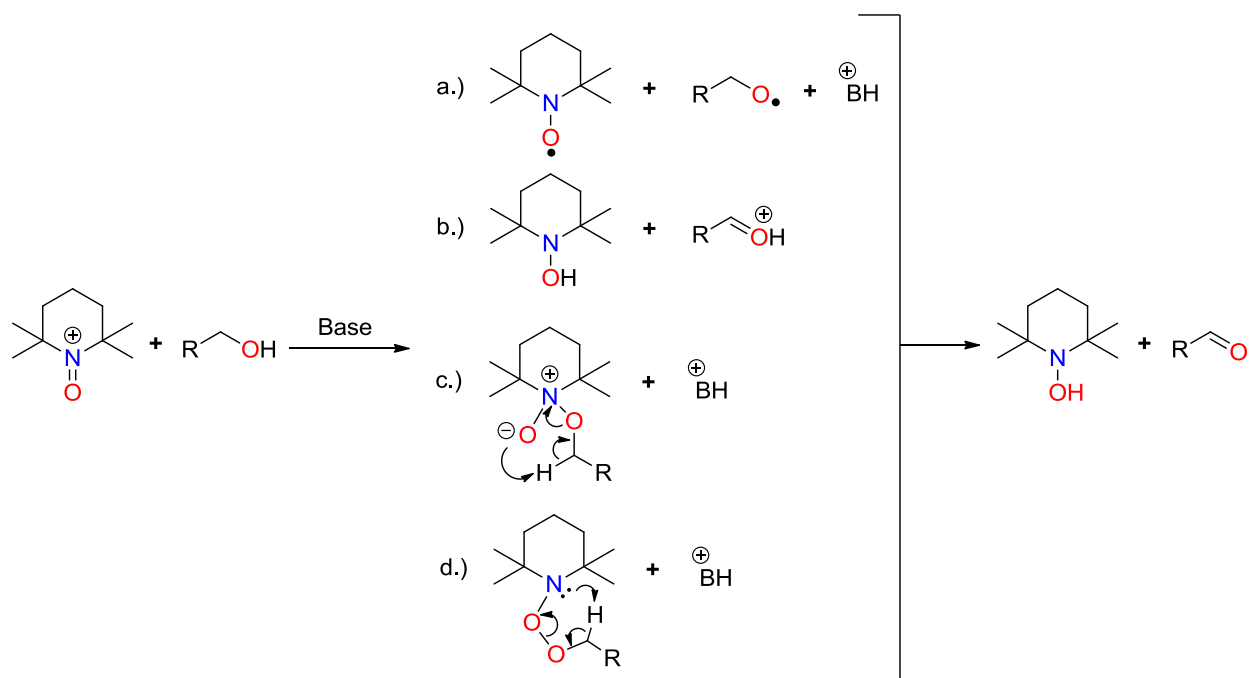


Chart 1-1

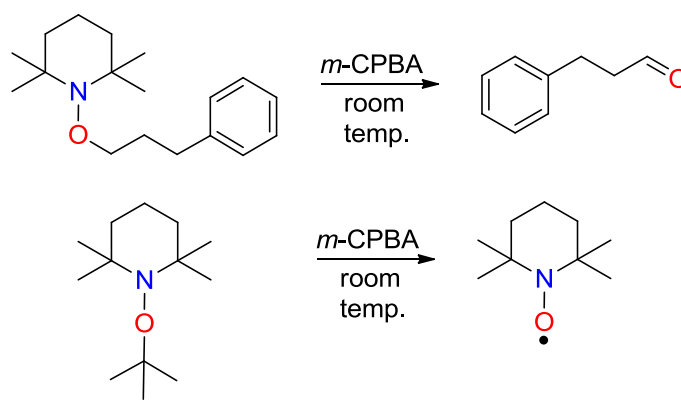
Semmelhack and coworkers postulated, that since 4-nitrobenzyl alcohol and 4-methylbenzyl alcohol had relative rates of 1.0 and 2.2, respectively, the difference in rates were not significant and there is only a slight development of a positive charge on the benzylic carbon in the rate-determining step. This process is inconsistent with a simple hydride abstraction mechanism.²⁹ They cited the following as strong evidence that the mechanism cannot involve a long-lived carbocation or radicals centered at the hydroxyl-bearing carbon: (a) the lack of reactivity of oxoammonium salts with triphenylmethane and simple ethers, which should be able to accommodate the loss of a hydride, and (b) the stability of chrysanthemyl alcohol under the general oxidation conditions which provides the corresponding aldehyde rather than undergoing a rearrangement process.



Scheme 1-9

A noteworthy observation from Semmelhack's work was that there is a significant primary hydrogen isotope effect (ca. 2.1 between unlabeled and deuterium-labeled substrates) in both intramolecular and intermolecular competition studies. Thus the rate-determining step of the oxidation is the removal of the proton or hydride from the hydroxyl-bearing carbon.²⁹ This led to the proposal that an intermediate complex must form and collapse to furnish the products, as shown in Scheme 1-9 (pathways c and d). Distinguishing between the two pathways was challenging since no intermediates were isolated or observed spectroscopically. Attempts to synthesize intermediates of the structure shown in pathway c of Scheme 1-9 failed, however when the propylphenyl adduct shown in Scheme 1-10 was treated with *m*-chloroperoxybenzoic acid (*m*-CPBA), 3-phenylpropanal resulted. This led to the conclusion that pathway c was a possible avenue for which the oxidation proceeds. It is interesting to note that when the *t*-butyl adduct in Scheme 1-10 was treated with *m*-CPBA the nitroxide was furnished as the major product and no other products were detected. The site of addition of oxygen nucleophiles to oxoammonium salts has yet to be firmly established; however, Golubev and coworkers reported the synthesis of alkali salts from oxoammonium cations.³⁰ Attempts to synthesize derivatives containing an oxygen-oxygen bond such as

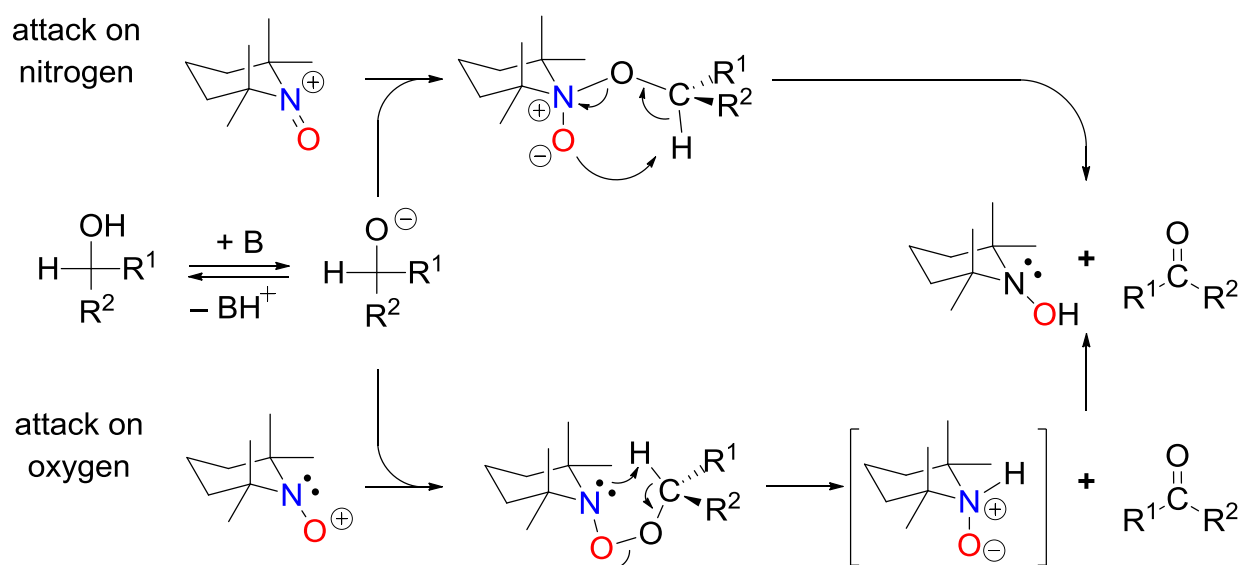
the intermediate shown in pathway d (Scheme 1-9) were also unsuccessful. When potassium *tert*-butoxide was added to a solution of oxoammonium salt at $-78\text{ }^{\circ}\text{C}$, no reaction occurred, but upon warming to room temperature the nitroxide was recovered as the sole product. Based on the experimental data, Semmelhack proposed that pathway c was more likely than pathway d, but pathway d could not be ruled out. Both pathways support the preferential oxidation of primary alcohols over secondary alcohols as the transition state is less sterically crowded during the oxidation of primary alcohol substrates when compared to secondary alcohols.^{24,31}



Scheme 1-10

More recently, Bailey, Bobbitt, and Wiberg have computationally investigated the oxidation of alcohols under basic conditions by oxoammonium salts at the B3LYP/6-31+G* level providing further information about the mechanism of such oxidations.²⁰ Computationally, it was found that under basic conditions an adduct must form between the substrate and the oxoammonium cation and that formation of this adduct, as originally proposed by Semmelhack, was indeed plausible. It was found that in acetonitrile solution the formation of a complex between the nitrogen of the oxoammonium cation and an alkoxide (OMe^- , OEt^- , Oi-Pr^-) was favorable by -17.9 , -13.8 , and -9.6 kcal/mol, respectively, and occurs via approach of the alkoxide from the side with the equatorial methyl groups. As the steric bulk of the alkoxide increases, complex formation is less favorable; this supports the fact that primary alcohols are oxidized much faster than secondary alcohols under basic conditions.³¹ It should be noted that, in acetonitrile solvent, complex formation between methoxide and the nitrogen of the oxoammonium cation

is computed to be higher in energy (9.1 kcal/mol) than complex formation of methoxide with the oxygen of the oxoammonium cation, and this is likely due to unfavorable steric interactions between the substrate and the bulky methyl groups of the oxoammonium salt. However, formation of the alkoxide-oxygen complex would result in a very weak peroxide bond and its energy of formation is higher than that of the transition state for the oxidation of methoxide to formaldehyde via the nitrogen-centered adduct (4.5 kcal/mol in acetonitrile solvent) formed by the equatorial approach of methoxide on the nitrogen of the oxoammonium salt.²⁰



Scheme 1-11

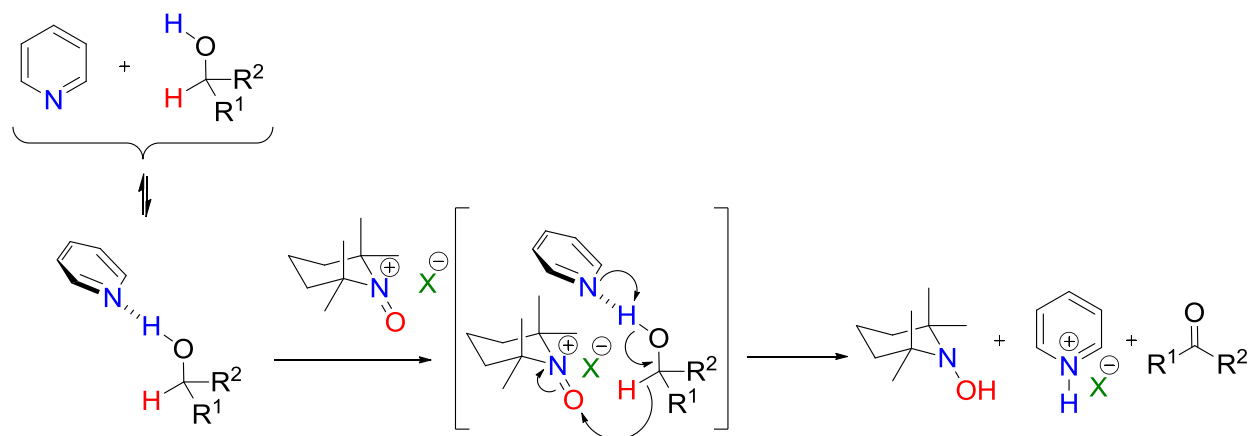
In summary, the mechanism of oxidation of alcohols under strongly basic conditions has been generally accepted to proceed via one of the two pathways illustrated in Scheme 1-11. The computational investigation of the process suggests that the most probable pathway for the oxidation is via equatorial attack of the alkoxide on the positive nitrogen of the oxoammonium salt to form an intermediate complex, which is followed by a hydrogen abstraction by the negative oxygen atom of the complex to furnish the hydroxylamine and the oxidation product. When stronger, more basic carbon nucleophiles such as enolates, Grignard reagents, or organolithiums are added to the oxoammonium salt a new oxygen-carbon bond is formed as the positive oxygen of the oxoammonium salt is preferentially attacked by these

nucleophiles.^{23, 24} For this reason, the pathway in which the alkoxide attacks the oxygen atom of the oxoammonium salt cannot be fully ruled out as the intermediate may be too unstable to isolate or observe.

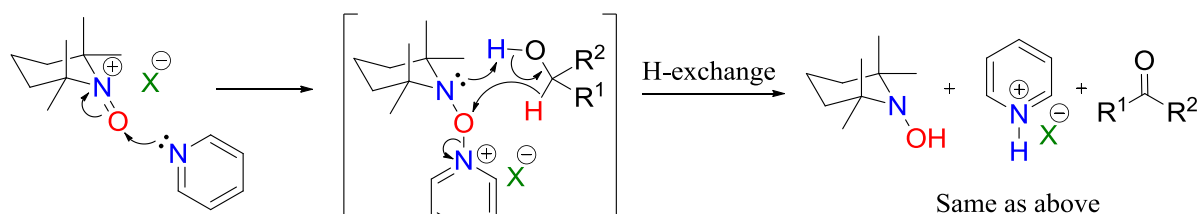
Under less basic conditions, such as oxidations in the presence of pyridine bases or those catalyzed by bleach, the oxidation of alcohols by oxoammonium salts has been proposed to take place under yet another mechanism. When pyridine bases are employed, the alcohol does not exist primarily as the alkoxide, therefore, the oxidation likely proceeds in a different manner. When pyridine itself is employed as the base, dimeric esters are formed as the major product; not the desired aldehyde.³² This is the result of the fact that pyridine itself is known to react with aldehydes in an equilibrium process to yield a betaine, which is rapidly oxidized by oxoammonium salts into an *N*-acylpyridinium intermediate, which is rapidly attacked by the alcohol substrate to furnish the dimeric ester.²² However, if 2,6-lutidine is employed the formation of a betaine between the base and the aldehyde does not occur due to the steric constraints of the nitrogen of 2,6-lutidine which is flanked by two bulky methyl groups; this allows for the efficient and conversion of alcohols to aldehydes in excellent yields.^{22, 29} Two proposed mechanisms for the process are shown in Scheme 1-12. The first mechanism invokes the formation of a hydrogen-bonded pre-reaction complex between the alcohol and a molecule of pyridine. This allows for the removal of a hydride from the alcohol substrate by the oxoammonium salt and employs the pyridine as an external base that functions to help deprotonate the alcohol in a concerted process or the protonated oxonium intermediate in a stepwise process.

This concerted process would likely explain why oxidations under basic conditions proceed at a much faster rate than oxidations conducted under acidic or neutral conditions. Additionally, since the oxidation involves the removal of a hydride in the transition state as depicted in Scheme 1-12, one would expect that electron-rich alcohols would oxidize faster than electron-deficient alcohols, and indeed there are differences in the rate of oxidation of substituted benzyl alcohols. For example, *p*-methoxybenzyl alcohol is oxidized 1.2 times faster than benzyl alcohol, whereas, *p*-nitrobenzyl alcohol is oxidized at half the rate of benzyl alcohol.²²

H-Bonding Mechanism:



Pyridinium Intermediate Mechanism:



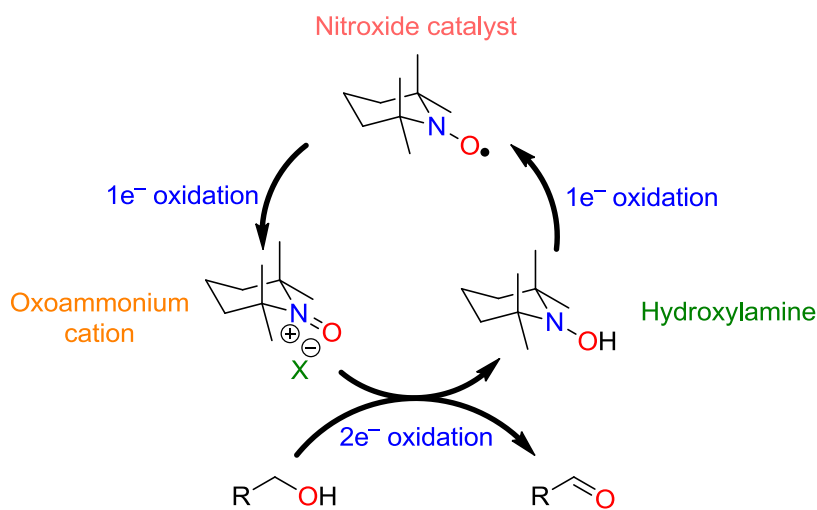
Scheme 1-12

Primary alcohols are oxidized more rapidly than secondary alcohols, which is possibly a kinetically-driven process; in primary alcohols, there are two possible hydrides to be removed AND the transition state is much less hindered as any substituents on the alcohol would be positioned one carbon-carbon bond length further away from the bulky methyl groups of the oxoammonium cation. This is demonstrated by the fact that even though neopentyl alcohol is a primary alcohol, it is oxidized at a rate 10 times slower than that of octanol.²² Additionally, 3-pentanol is oxidized at a rate half that of the more sterically-hindered 1-phenylethanol,²² which is sufficiently explained by the electronic differences of the substrates. The aromatic system of 1-phenylethanol helps to stabilize the developing positive charge in the transition state, this electronic stabilization is absent in 3-pentanol. Therefore, the oxidation of alcohols by oxoammonium salts under weakly basic conditions proceeds analogously to the neutral or acidic process; a hydride is removed from the alcohol substrate by the oxoammonium cation. A rate

difference between the two processes is observed since the external base helps to deprotonate the substrate in the transition state, thus accelerating the oxidation under weakly basic conditions. The acidic/neutral oxidation of alcohols by oxoammonium salts is selective for secondary and electron-rich alcohols a result of the fact that the process is slower, thus the electronics of the substrate and the ability to stabilize the transition state dictate the rate of reaction to a greater extent than under weakly basic conditions. Under weakly basic conditions primary alcohols can be selectively oxidized over secondary alcohols, likely the result of a kinetically-driven process. Thus, what arises is a very selective oxidant, as simple and slight modification of reaction conditions allows for the controlled, selective oxidation of alcohol substrates.

1.3 The Oxidation/Reduction Cycle of Oxoammonium Salt Oxidants

The unique oxidation/reduction cycle as well as other properties of oxoammonium salt oxidants allows for the following: a) the recovery and recycling of the spent oxidant from stoichiometric oxidations b) the development of catalytic processes through use of less expensive secondary oxidants and c) favorable, differentiable solubility properties that simplify the work-up process and product isolation. While briefly touched upon in Scheme 1-5 and Chart 1-1, a general illustration of the overall oxidation/reduction cycle is depicted in Scheme 1-13.



Scheme 1-13

Oxoammonium salts can be prepared in a number of ways,¹⁰ but usually, are prepared from either a two-electron oxidation of a hydroxylamine or a one-electron oxidation of a nitroxide. The oxidative cycle is tied together by these three main components, and the understanding of this cycle allows for one to obtain any one of the three components from the other; this allows for a recyclable oxidant.

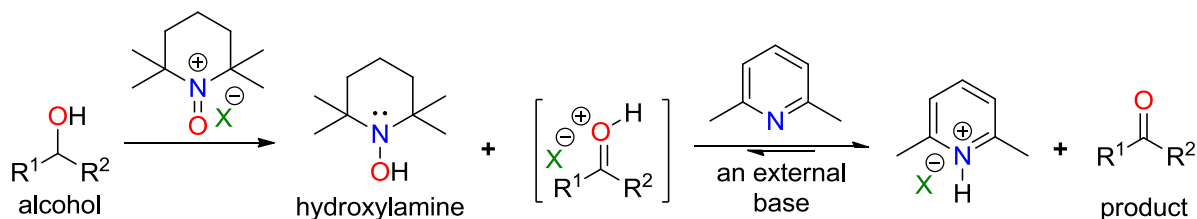
Another important feature of these three components is the inherent differences in solubility. Oxoammonium salts, in general, are relatively insoluble in non-polar hydrocarbon or weakly-polar ethereal solvents, whereas exhibit partial solubility in halogenated solvents and are fairly soluble in polar solvents such as water and acetonitrile. Nitroxides tend to be fairly insoluble in non-polar and ethereal solvents and exhibit moderate to complete solubility in halogenated and more polar solvents. The hydroxylamine derivatives, as the free amine, are moderately soluble in a wide range of solvents, but when acidified, the amine salts tend to be insoluble in the majority of organic solvents and are most easily dissolved in very polar solvents such as water or acetonitrile. Depending on how the oxidation is conducted, the oxoammonium salt will be reduced to either the protonated hydroxylamine derivative or the nitroxide.

For oxidations of alcohols conducted under neutral conditions the oxoammonium salt is reduced to the hydroxylamine as the two-electron oxidation results in the hydroxylamine, which acts as a base removing a proton from the intermediate furnishing the protonated hydroxylamine. Simple filtration of the reaction mixture through a plug of silica gel with an ethereal, halogenated, or non-polar solvent is sufficient to separate the protonated hydroxylamine from the oxidized product. Alternatively, if desired, filtration of the reaction mixture through filter paper with a non-polar or ethereal solvent allows for the hydroxylamine to be recovered and recycled back into the oxoammonium salt oxidant.

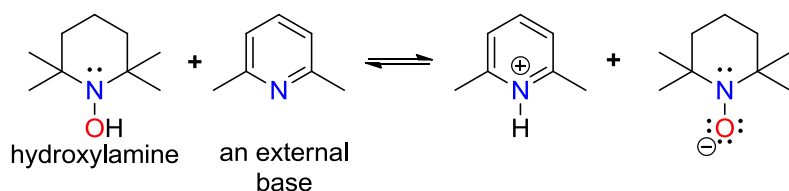
When oxidations are conducted under basic conditions, as illustrated in Scheme 1-14, the substrate undergoes a two-electron oxidation initially reducing the oxoammonium salt to the hydroxylamine, and the external base helps to deprotonate the intermediate. Additionally, there is an acid-base equilibrium to consider; the resulting hydroxylamine can be deprotonated by the external base. The equilibrium constant for the process may be relatively small ($K_{eq} \ll 1$; $K_{eq} \approx 3.2 \times 10^{-9}$, calculated

using the pKa values of pyridine³³ = 5.2 and the hydroxylamine³⁴ ~ 13.7), but the removal of a proton from the hydroxylamine initiates a very fast side reaction ($k \approx 3.3 \times 10^4 \text{ M}^{-1}\text{s}^{-1}$)³⁴ with an oxoammonium salt driving the reaction to completion. This is known as a comproportionation³⁵ process, and has been suggested^{34,36} to proceed via a single-electron-transfer (SET); the deprotonated hydroxylamine donates an electron to a molecule of oxoammonium salt resulting in the formation of two molecules of nitroxide (Scheme 1-14). This process is pH dependent and only occurs at above neutral conditions (pH > 7).

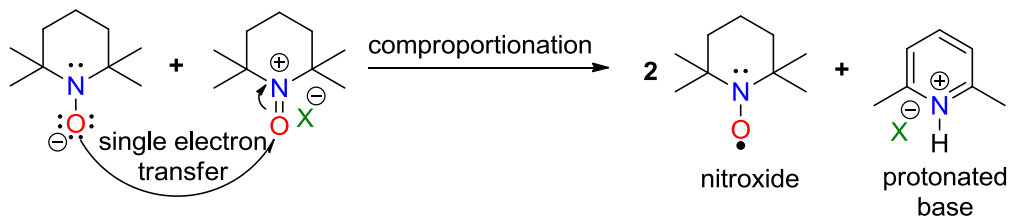
Initial oxidation process:



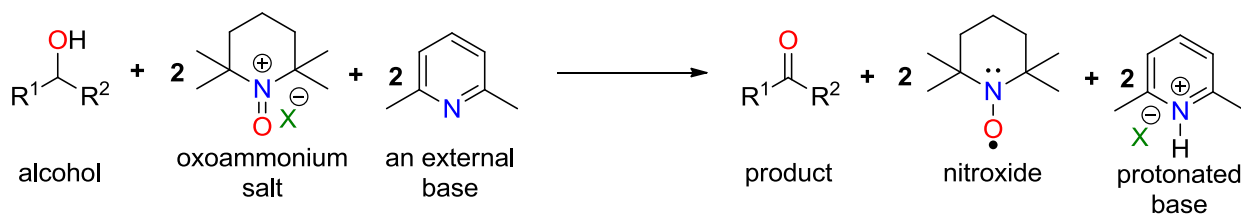
Except:



And:



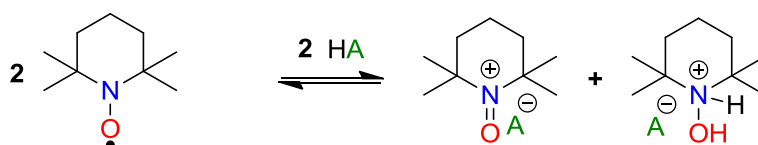
Overall stoichiometry:



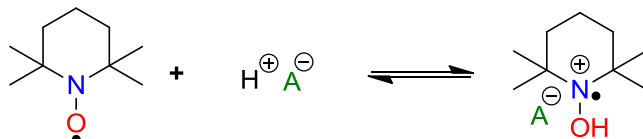
Scheme 1-14

As Golubev and coworkers were first to discover,^{8,37} the comproportionation process is reversible. When exposed to strongly acidic conditions, two nitroxide molecules disproportionate into a molecule of oxoammonium salt and a molecule of a protonated hydroxylamine salt (Scheme 1-15). The first oxoammonium salts were prepared⁸ through the disproportionation of stable nitroxides, and shortly thereafter, a mechanism was proposed for the process.³⁸ More recently, Sen' and Golubev reinvestigated the proposed mechanism of the acid-catalyzed disproportionation (Scheme 1-15), and measured the kinetics for the process using TEMPO as a model substrate.³⁹ It was noted that nitroxides, in general, exhibit a low basicity and those containing electron-withdrawing groups are even less basic, but more stable under acidic conditions.^{39,40}

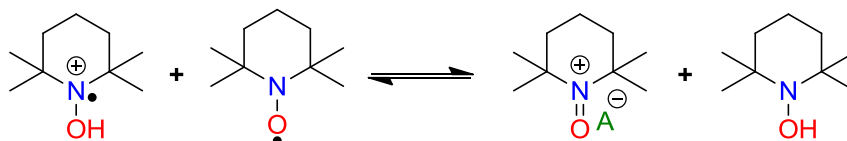
Overall Stoichiometry:



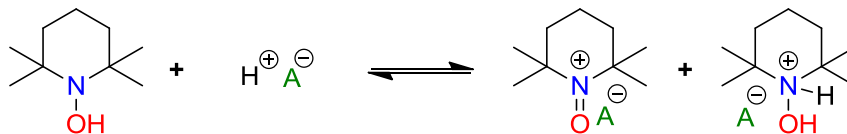
Step 1:



Step 2:



Step 3:



Scheme 1-15

Due to the reversibility of the comproportionation–disproportionation process, it is possible to develop catalytic or recyclable methods for oxidation starting at any point along the redox cycle using an oxoammonium salt, hydroxylamine, or nitroxide along with the proper secondary oxidant. A plethora of

catalytic methods¹⁰ are currently available, and new methods are actively developed. A key aspect of many catalytic methods, that is often misinterpreted, is that the oxoammonium salt is the active oxidant within the redox cycle, not the nitroxide, and it must be actively regenerated using a secondary oxidant. A thorough understanding of this concept, as well as, the unique redox cycles of oxoammonium salt oxidants allows for one to develop novel and selective oxidative methods. While the majority of oxoammonium salt chemistry has focused on the selective oxidation of oxygen-containing substrates, until recently, the selective oxidation of nitrogen-containing substrates has been largely ignored.

References Chapter I

- ¹ It should be noted that terms such as nitrosonium, immonium oxide, iminoxyl, and oxoamminium have been used
- ² Frémy, E. *Ann. Chim. Phys.* **1845**, 15, 408–488.
- ³ Parker, K. A.; Su, D.-S. Potassium Nitrosodisulfonate. *Encyclopedia of Reagents for Organic Synthesis*. [Online] **2001**. <http://onlinelibrary.wiley.com/doi/10.1002/047084289X.rp243/full> (accessed Feb 3, 2017) and references therein.
- ⁴ Wieland, H.; Offenbächer, M. *Chem. Ber.* **1914**, 47, 2111–2115.
- ⁵ (a) Lebedev, O. A.; Kazarnovskii, S. N. *Trudy po Khimii i Khim. Technologii (Gorkii)* **1959**, 8, 649. (b) Neiman, M. B.; Rozantzev, É. G.; Mamedova, Y. G. *Nature* **1962**, 196, 472–474. (c) Rozantsev, É. G.; Neiman, M. B. *Tetrahedron*, **1964**, 20, 131 – 137. (d) Briere, R.; Lemaire, H.; Rassat, A. *Bull. Soc. Chim. Fr.* **1965**, 32, 3273 – 3283.
- ⁶ For a review of nitroxides see: (a) Keana, J. F. W. *Chem. Rev.* **1978**, 78, 37–67. (b) Bobbitt, J. M.; Brückner, C.; Merbouh, N. *Org. React. (NY)* **2010**, 74, 103–424 and references therein.
- ⁷ Lantzsich, R.; Arlt, D. (Bayer Aktiengesellschaft). Process for preparing 4-amino-2,2,6,6-tetramethylpiperidine. U.S. Patent 4,001,250, February 24, 1975.
- ⁸ Golubev, V. A.; Rozantzev, É. G.; Neiman, M. B. *Bull. Acad. Sci. USSR, Div. Chem. Sci.* **1965**, 14, 1898–1904.
- ⁹ (a) Meyer, K. H.; Gottlieb-Billroth, H. *Chem. Ber.* **1919**, 52, 1476–1489. (b) Meyer, K. H.; Reppe, W. *Chem. Ber.* **1921**, 54, 327–336. (c) Meyer, K. H.; Elbers, W. E. *Chem. Ber.* **1921**, 54, 337–346.
- ¹⁰ For a review of oxoammonium salt oxidations see reference 6b along with: (a) Bobbitt, J. M.; Flores, C. L. *Heterocycles* **1988**, 27, 509–533. (b) Merbouh, N.; Bobbitt, J. M.; Brückner, C. *Org. Prep. Proced. Int.* **2004**, 36, 1–31 and references therein.
- ¹¹ Miyazawa, T.; Endo, T.; Shiihashi, S.; Okawara, M. *J. Org. Chem.* **1985**, 50, 1332–1334.
- ¹² Sen', V. D.; Golubev, V. A. *Russ. Chem. Bull.* **1993**, 43, 500–507.
- ¹³ Bobbitt, J. M. *J. Org. Chem.* **1998**, 63, 9367–9374.
- ¹⁴ Zhdanov, R. I.; Golubev, V. A.; Rozantzev, É. G. *Bull. Acad. Sci. USSR, Div. Chem. Sci.* **1970**, 19, 188–190.
- ¹⁵ Shibuya, M.; Tomizawa, M.; Iwabuchi, Y. *J. Org. Chem.* **2008**, 73, 4750–4752.
- ¹⁶ (a) Inokuchi, T.; Matsumoto, S.; Fukushima, M.; Torii, S. *Bull. Chem. Soc. Jpn.* **1991**, 64, 796–800. (b) Inokuchi, T.; Matsumoto, S.; Nishiyama, T.; Torii, S. *J. Org. Chem.* **1990**, 55, 462–466.
- ¹⁷ Bobbitt, J. M. *Chem. Eng. News* **1999**, 77, 6.
- ¹⁸ Mercadante, M. A.; Kelly, C. B.; Bobbitt, J. M.; Tilley, L. J.; Leadbeater, N. E. *Nat. Protoc.* **2013**, 8, 666–676.
- ¹⁹ Golubev, V. A.; Borislavskii, V. N.; Aleksandrov, A. L. *Russ. Chem. Bull.* **1977**, 26, 1874–1881.
- ²⁰ Bailey, W. F.; Bobbitt, J. M.; Wiberg, K. B. *J. Org. Chem.* **2007**, 72, 4504–4509.
- ²¹ Hamlin, T. A.; Kelly, C. B.; O'vian, J. M.; Wiles, R. J.; Tilley, L. J.; Leadbeater, N. E. *J. Org. Chem.* **2015**, 80, 8150–8167.
- ²² Bobbitt, J. M.; Bartelson, A. L.; Bailey, W. F.; Hamlin, T. A.; Kelly, C. B. *J. Org. Chem.* **2014**, 79, 1055–1067.
- ²³ Golubev, V. A.; Kobylanskii, E. V. *Zh. Org. Khim.* **1972**, 8, 2607–2613.
- ²⁴ Semmelhack, M. F.; Schmid, C. R.; Cortés, D. A. *Tetrahedron Lett.* **1986**, 27, 1119–1122.
- ²⁵ Pradhan, P. P.; Bobbitt, J. M.; Bailey, W. F. *Org. Lett.* **2006**, 8, 5485–5487.
- ²⁶ Hunter, D. H.; Barton, D. H. R.; Motherwell, W. J. *Tetrahedron Lett.* **1984**, 25, 603–606.
- ²⁷ Golubev, V. A.; Rudyk, T. S.; Sen', V. A.; Aleksandrov, A. L. *Russ. Chem. Bull.* **1976**, 25, 744–750.
- ²⁸ Cella, J. A.; Kelley, J. A.; Kennehan, E. F. *J. Org. Chem.* **1975**, 40, 1860–1862.
- ²⁹ Semmelhack, M. F.; Chou, C. S.; Cortes, D. A. *J. Am. Chem. Soc.* **1983**, 105, 4492–4494.
- ³⁰ Golubev, V. A.; Sen', V. A.; Rozantzev, É. G. *Russ. Chem. Bull.* **1979**, 29, 1927–1931.
- ³¹ de Nooy, A. E. J.; Besemer, A. C.; Bekkum, H. V. *Tetrahedron* **1995**, 51, 8023–8032.
- ³² Merbouh, N.; Bobbitt, J. M.; Brückner, C. *J. Org. Chem.* **2004**, 69, 5116–5119.
- ³³ Anslyn, E. V.; Dougherty, D. A. *Modern Physical Organic Chemistry*; University Science Books: Mill Valley, CA, 2006; p 281.
- ³⁴ Israeli, A.; Patt, M.; Oron, M.; Samuni, A.; Kohen, R.; Goldstein, S. *Free Radic. Biol. Med.* **2005**, 38, 317–324.
- ³⁵ “Comproportionation” is a term used to describe a process where two different molecules (i.e. a molecule of an oxoammonium salt and a molecule of deprotonated hydroxylamine) have undergone a chemical reaction with one another to provide two molar equivalents of the same molecule (i.e. two molecules of nitroxide).
- ³⁶ Sen', V. D.; Tikhonov, I. V.; Borodin, L. I.; Pliss, E. M.; Golubev, V. A.; Syroeshkin, M. A.; Rusakov, A. I. *J. Phys. Org. Chem.* **2015**, 28, 17–24.

- ³⁷ Golubev, V. A.; Zhdanov, R. I.; Gida, V. M.; Rozantsev, E. G. *Bull. Acad. Sci. USSR, Div. Chem. Sci.* **1971**, 20, 768–770.
- ³⁸ Golubev, V. A.; Sen', V. D.; Kulyk, I. V.; Aleksandrov, A. L. *Bull. Acad. Sci. USSR, Div. Chem. Sci.* **1975**, 24, 2119–2126.
- ³⁹ Sen', V. D.; Golubev, V. A. *J. Phys. Org. Chem.* **2009**, 22, 138–143.
- ⁴⁰ Tikhonov, I. V.; Sen', V. D.; Borodin, L. I.; Pliss, E. M.; Golubev, V. A.; Rusakov, A. I. . *J. Phys. Org. Chem.* **2014**, 27, 114–120.

CHAPTER II. OXOAMMONIUM SALT OXIDATIONS OF PRIMARY AMINES, ALCOHOLS, AND ALDEHYDES TO AFFORD NITRILES AND RELATED CHEMISTRY

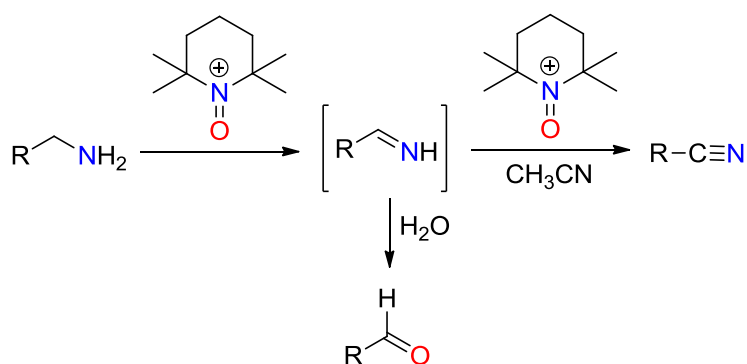
2.1 Introduction to Oxoammonium Salt Oxidations of Amines

Amine-containing substrates are challenging to oxidize vis-à-vis alcohol counterparts, as an assortment of products are possible depending on the choice of oxidant and reaction conditions.¹ The oxidation of primary amines to imines requires a dehydrogenation reaction.² A more challenging oxidation is the conversion of primary amines to nitriles. Incorporation of the nitrile functionality into synthetic targets through direct, environmentally benign, and economical approaches is of central interest to the pharmaceutical and agrochemical industries.³ Nitriles serve as precursors to access other functionalities^{4,5} such as amides and acids,⁶ heterocycles,⁷ as well as synthetic polymers.⁸ However, despite a plethora of methods to obtain nitriles,⁹ the direct oxidation of primary amines is not a conventionally utilized route. Traditional methods for the preparation of nitriles employ often toxic cyanating reagents.^{4,10} A less common, but practical, approach involves the oxidation of primary amines to nitriles, as amine-containing substrates are abundant and readily available; this work was aimed at expanding this area.

Amines are known to react with oxoammonium salts, but until recently have been largely ignored as concisely stated by Bobbitt: “the reactions are best avoided and are not very useful.”^{11, 12, 13} Much more work needs to be done.”¹⁴ Initial studies into the oxidation of primary amines to nitriles by oxoammonium salts were conducted electrochemically or catalytically employing a secondary oxidant, and generally, were not very selective.

Semmelhack and Schmid were first to report, in 1983, the electrochemical oxidations of amines using a TEMPO catalyst.¹⁵ In this work, under anhydrous conditions, amines were converted to nitriles by an oxoammonium cation generated by the electrochemical oxidation of TEMPO. Under aqueous conditions, primary amines were converted to aldehydes in addition to the nitrile. It was postulated that the two products were formed via an imine intermediate. Subsequent oxidation of the imine intermediate

by the oxoammonium cation led to the formation of the nitrile product under anhydrous conditions. When water is present in the solvent system, hydrolysis of the imine intermediate yields the observed carbonyl compounds (Scheme 2-1). Thus, TEMPO-catalyzed electrochemical oxidation of amines may afford nitriles or carbonyl-containing compounds depending on the conditions. Only a small number of pure nitriles, summarized in Table 2-1, were reported in this communication. A similar oxidation, reported by MacCorquodale et al., employed poly(2,2,6,6-tetramethylpiperidiny1-N-oxyl-4-acrylic ester) (Figure 2-1), as the electrocatalyst.¹⁶



Scheme 2-1

Kashiwagi et al. expanded on the electrosynthetic work of both Semmelhack¹⁵ and MacCorquodale¹⁶ using a TEMPO-modified graphite felt electrode to selectively oxidize amines to nitriles.¹⁷ Four amine substrates (benzylamine, 2-phenylethylamine, *p*-methoxybenzylamine, and nonylamine) were oxidized to the corresponding nitriles under anhydrous conditions with reported conversions in the range of 69 – 82% with greater than 95% selectivity for formation of nitrile product.

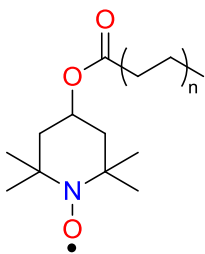


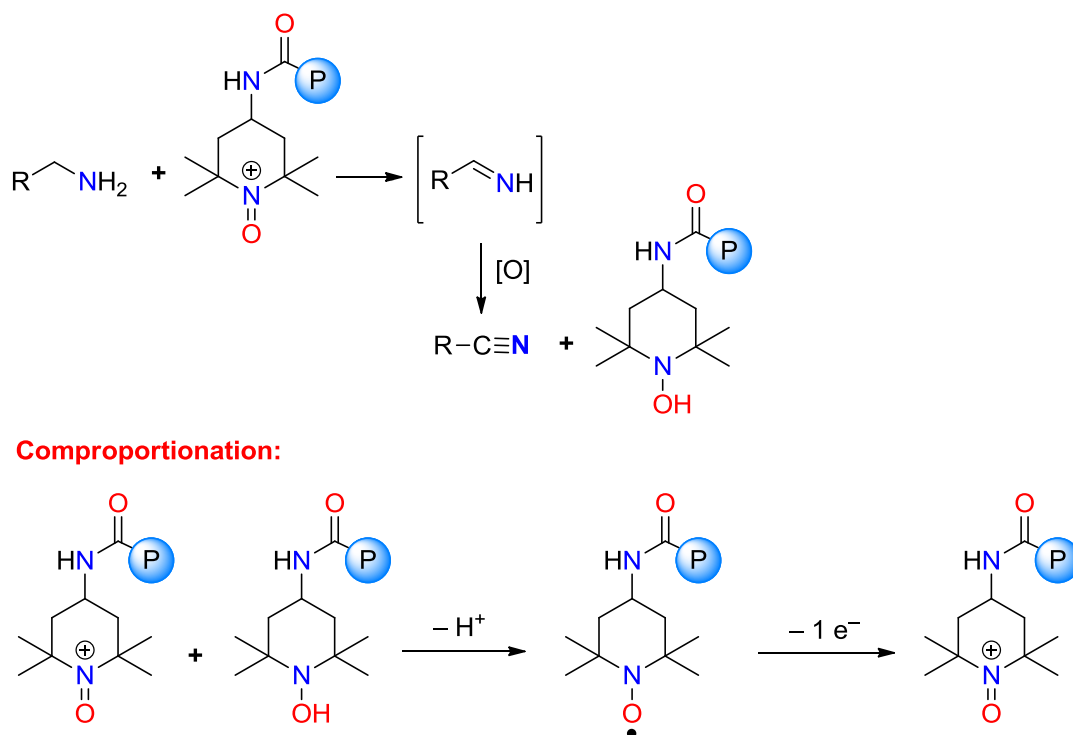
Figure 2-1

Table 2-1

$\text{R-NH}_2 \xrightarrow[\text{CH}_3\text{CN, +0.33V}]{\text{2,6-lutidine, LiClO}_4}$
 $\text{R-C}\equiv\text{N}$

entry	amine	product	isolated yield (%)
1	$\text{Ph}(\text{CH}_2)_3\text{NH}_2$	$\text{Ph}(\text{CH}_2)_2\text{CN}$	78
2	$p\text{-MeOC}_6\text{H}_4\text{CH}_2\text{NH}_2$	$p\text{-MeOC}_6\text{H}_4\text{CN}$	85
3	piperonylamine	piperonylnitrile	85

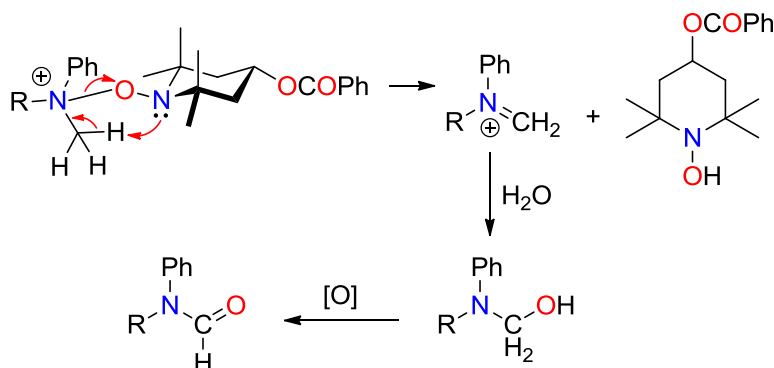
Similar to Semmelhack and Schmid,¹⁵ the proposed mechanism involved an imine intermediate, followed by a second oxidative process to afford the nitrile product (Scheme 2-2). The imine intermediate was not isolated, and under these anhydrous conditions was oxidized to the nitrile. Additionally, as in all nitroxide-catalyzed electrochemical oxidations, the hydroxylamine product reacts with the oxoammonium ion to regenerate the nitroxide and fulfill the catalytic cycle.



Scheme 2-2

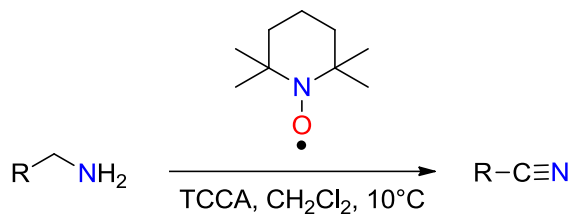
The previously discussed oxidations explored the reactions of primary amine substrates. Hunter et al. were the first to study the stoichiometric oxidation of *N*-alkyl-*N*-methylanilines with oxoammonium salts; formamides were the major products observed in these reactions.¹⁸ It was postulated that an imine intermediate was hydrolyzed to a primary alcohol and then further oxidized by the oxoammonium cation to the formamide. The proposed mechanism is depicted in Scheme 2-3. Similar results were obtained when Kashiwagi and Anzai studied the electrochemical oxidations of tertiary amines with a TEMPO catalyst in aqueous media.¹⁹

Another avenue to generate the active oxoammonium cation from a nitroxide radical involves the introduction of a secondary oxidant. However, the nature of the secondary oxidant must be carefully considered as amines are susceptible to a variety of oxidative processes. There have been a limited number of examples of such systems reported and more recent studies employ Cu/TEMPO catalytic cycles for the synthesis of nitriles or imines.



Scheme 2-3

In 2003, Chen et al. published a method for the oxidation of aliphatic, aromatic, and heterocyclic primary amines to nitriles with trichloroisocyanuric acid (TCCA) in the presence of a catalytic amount of TEMPO. Their results are summarized in Table 2-2.²⁰ It might be noted that aliphatic amines (entries 1 & 2) were oxidized at a slower rate than arylamines. Additionally, the method tolerates conjugated double bonds (entry 6), but the reaction must be kept at 10 °C as TCCA easily chlorinates a variety of substrates.²¹ No mechanism was proposed for this oxidation, but it likely proceeds through an *N*-chloroamine intermediate, similar to the dehydrogenation of tetrahydroisoquinolines with TCCA.²¹

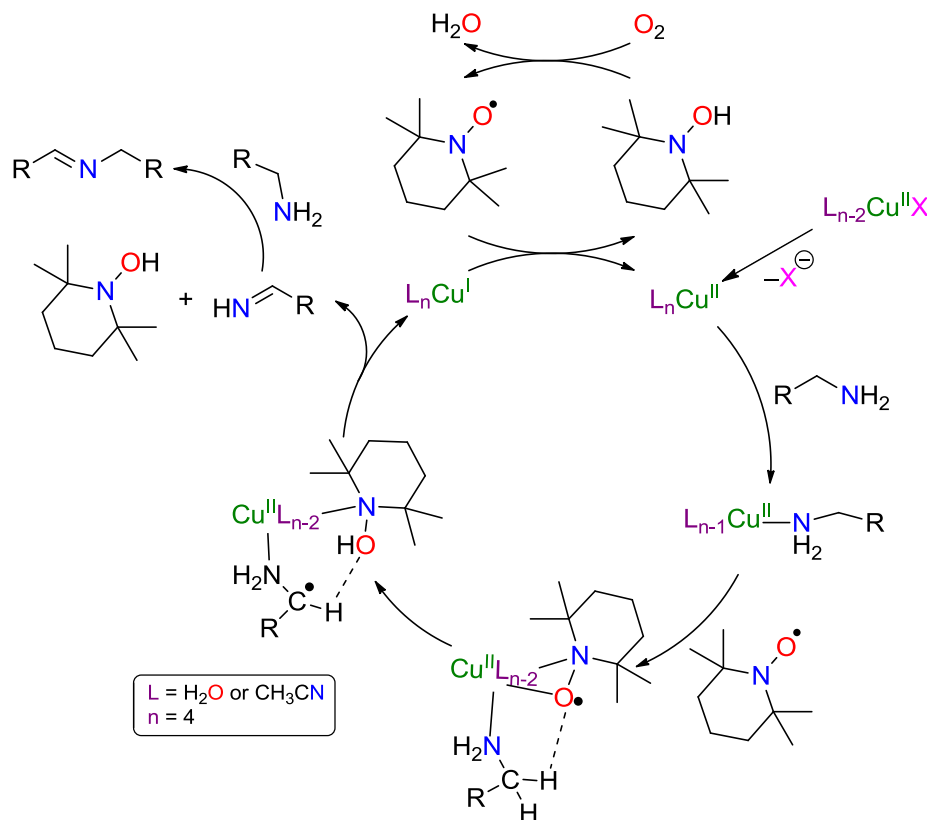
Table 2-2

entry	R	time (h)	isolated yield (%)
1	C ₅ H ₁₁	4	81
2	HO ₂ C(CH ₂) ₅	4.5	80
3	Ph	2	90
4	4-MeOC ₆ H ₄	2	90
5	4-NO ₂ C ₆ H ₄	2.5	90
6	(<i>E</i>)-PhCH=CH	2	90
7	1-naphthyl	1.5	90
8	3,4-(OH) ₂ C ₆ H ₃	2	91
9	2-furyl	2	89
10	3-pyridyl	2	89

Unlike the process described above employing TCCA, most oxidations of amines involve the use of transition metal catalysts. The use of transition metals in oxidative transformations of amines stemmed from early studies on transition metal complexes containing amine ligands. The origin of this chemistry was the keen observation by Beattie and Elsbernd that the impurity in ethylenediamine-ruthenium(II) and ruthenium(III) complexes was due to a deprotonated ligand.²² A report by McWhinnie and co-workers suggested that amine ligands were oxidized at room temperature to the corresponding nitriles.²³ Concurrently, Lane and co-workers observed that ethylenediamine ligands on ruthenium complexes were oxidized to imines, which were stable when coordinated with the transition metal.²⁴ These observations led to the development of various protocols for the oxidation of amines to nitriles or imines using

transition metals, including ruthenium,²⁵ iron,²⁶ nickel,²⁷ cobalt,²⁸ iridium,²⁹ and copper.³⁰ Initial oxidations involving mainly ruthenium catalysts were soon supplanted by Cu/TEMPO catalyst systems.³¹

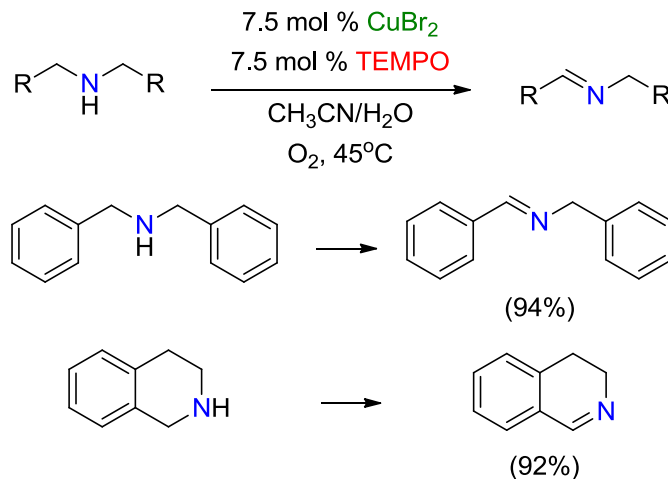
The first catalytic Cu/TEMPO systems developed for the oxidation of amines were aimed at imine formation, resulting from one oxidative step. Hu and Kerton in 2012 reported the first use of a Cu/TEMPO system for the oxidation of amines.³² In this study, a number of copper salts in combination with a TEMPO catalyst were explored for use in the conversion of benzylamine to the homocoupled imine product, *N*-benzylidenebenzylamine. The highest yield of product (86%) was achieved in 8 h using catalytic quantities of CuBr₂ and TEMPO in an acetonitrile/water (2:1) solvent at room temperature.



Scheme 2-4

The mechanism proposed for this transformation, which is similar to that previously advanced by Patil and Adimurthy,^{30f} is shown in Scheme 2-4. In short, a Cu(II) complex generated by oxidative insertion is oxidized by a radical pathway involving a hydrogen atom abstraction. Fragmentation of the

intermediate generates the aldimine and neutral hydroxylamine. The aldimine intermediate then couples with the initial amine substrate in a transamination process that releases ammonia. The resulting Cu(I) complex and the hydroxylamine are then re-oxidized by molecular oxygen completing the catalytic cycle. A number of substituted benzylic amines were oxidized to homocoupled imines in good yield (Table 2-3) and secondary amines were oxidized to imines using the same protocol (Scheme 2-5).



Scheme 2-5

Kerton and Hu³² observed that aldehydes were not generated in any of these reactions even though water was used as a co-solvent. It would seem that the amine reacts with the aldimine intermediate more quickly than water due to the Schotten-Baumann principle. Kanai et al. reported a more inclusive screening of TEMPO-derived catalysts for the oxidation of amines to imines, this led to the development of a preferred system using catalytic ketoABNO and $CuBr$.³³

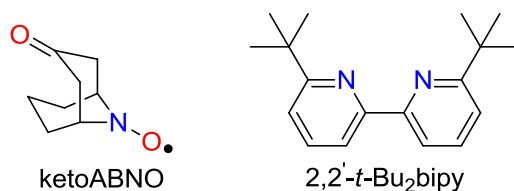





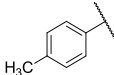


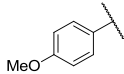
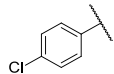
Figure 2-2

While ketoABNO is more expensive than the parent TEMPO system, this less sterically encumbered nitroxide allows for the oxidation of a broader scope of amines. Optimal results, using the

conditions depicted in Scheme 2-6, were reported for systems containing secondary benzylic amines giving isolated yields of 25 – 81%. Primary benzylic amine substrates were also oxidized under these conditions albeit giving lower isolated yields (34 – 48%) and amine substrates containing trityl and *p*-methoxyphenyl protecting groups did not give isolatable products. Aliphatic amines were not investigated in this work. It is important to note the oxidations required a 2,2'-*t*-butylbipyridyl ligand (Figure 2-2), molecular sieves to absorb water, an external base such as DMAP, and a polar solvent (THF).

Table 2-3

$$\text{R-CH}_2\text{-NH}_2 \xrightarrow[\text{CH}_3\text{CN/H}_2\text{O, O}_2 \text{ room temp}]{\text{5 mol \% CuBr}_2, \text{5 mol \% TEMPO}} \text{R-CH=N-R}$$

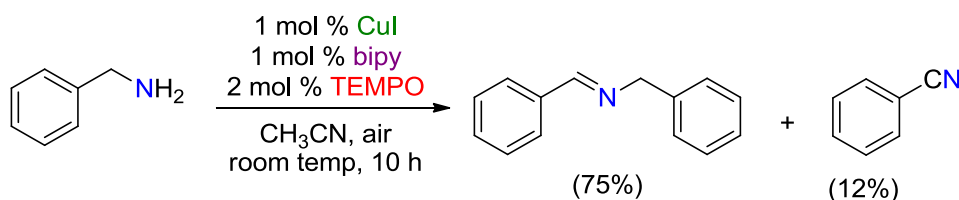
entry	R	isolated yield (%)	entry	R	isolated yield (%)
1		87	5		93
2		94	6		88
3		93	7		82
4		94	8		76

Using ESR and cyclic voltammetry some mechanistic insight into the reaction was provided. ESR measurements indicated that CuBr facilitated the oxidation of the *N*-hydroxylamine of ketoABNO to the *N*-oxyl radical. DMAP was not involved in this process. Cyclic voltammetry studies indicated that ketoABNO has a significantly higher oxidation potential than does TEMPO or ABNO. This higher oxidation potential is likely responsible for the ability of this system to oxidize hindered amines. The catalytic cycle proposed by Kanai et al.³³ is illustrated in Scheme 2-7.



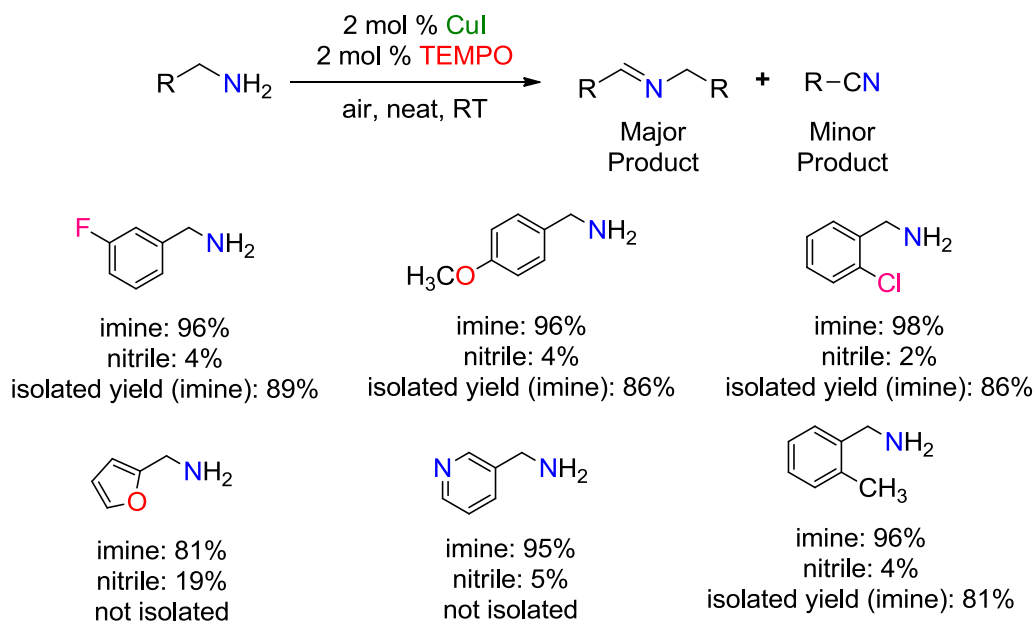
The catalytic cycle (Scheme 2-7) begins with the formation of a hydroxy/peroxy Cu(II) complex containing the ligand and ketoABNO bound to the copper. This complex was suggested to undergo a ligand exchange with the amine substrate accompanied by loss of water. The newly formed complex likely collapses through a radical transfer from the nitrogen to the copper center generating an aminyl radical, which would allow for a concerted α -hydrogen abstraction by the bound ketoABNO and subsequent release of an imine product. The DMAP likely facilitates release of the imine product as it is able to ligate to the Cu(I) center. Oxidation by molecular oxygen regenerates the initial hydroxyl/peroxy Cu(II) complex and the cycle then repeats.

While studying an oxidative coupling of alcohols and amines using a CuI/TEMPO system, Huang et al. accidentally discovered that amines could be oxidized to imines.³⁴ When the alcohol was omitted from the reaction the formation of homocoupled imines was observed. Expanding upon this observation they developed a system to oxidize amines to imines. They found when benzylamine was oxidized using their CuI/bipy/TEMPO system a mixture of imine and nitrile products were obtained as shown in Scheme 2-8.



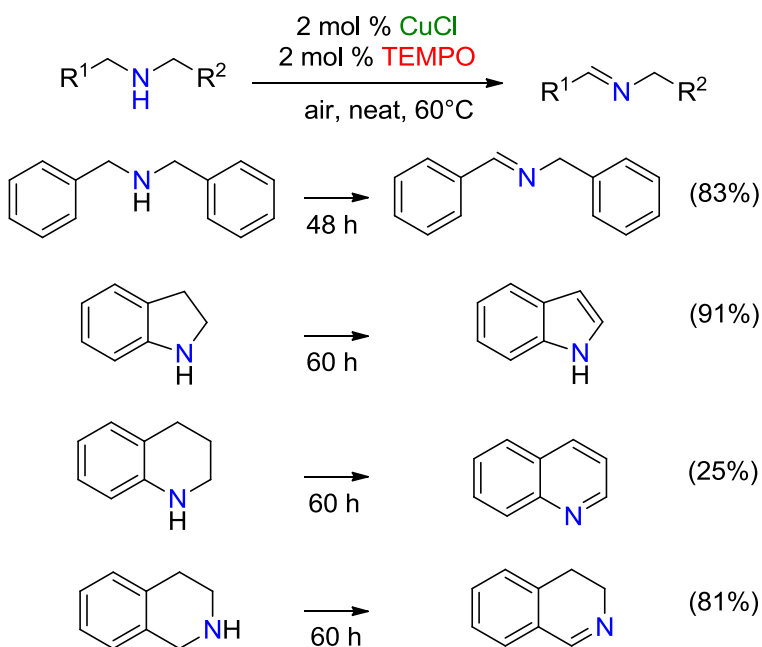
Scheme 2-8

The authors modified the reaction conditions to maximize the yield of imine products. Optimal conditions involved no solvent, 2 mol % CuI/TEMPO catalyst, at room temperature in a vessel open to air (Scheme 2-9). It should be noted that the bipyridyl ligand was not necessary to accomplish these oxidations in good yield.



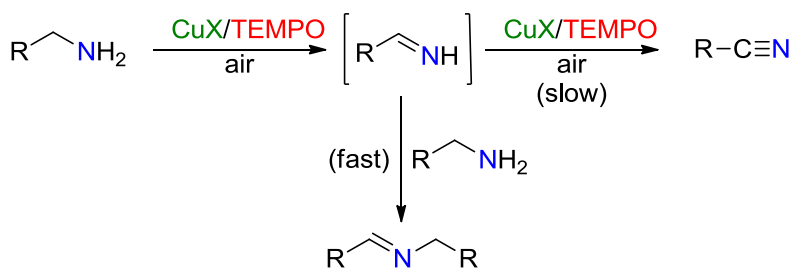
Scheme 2-9

In the oxidations reported by Huang et al.³⁴ small amounts of the nitrile and other by-products were observed. Secondary amines were also oxidized using a CuCl/TEMPO-catalyzed system to give the corresponding imines, however, higher temperatures (60°C) and longer reaction times were required to obtain respectable yields of product (Scheme 2-10).



Scheme 2-10

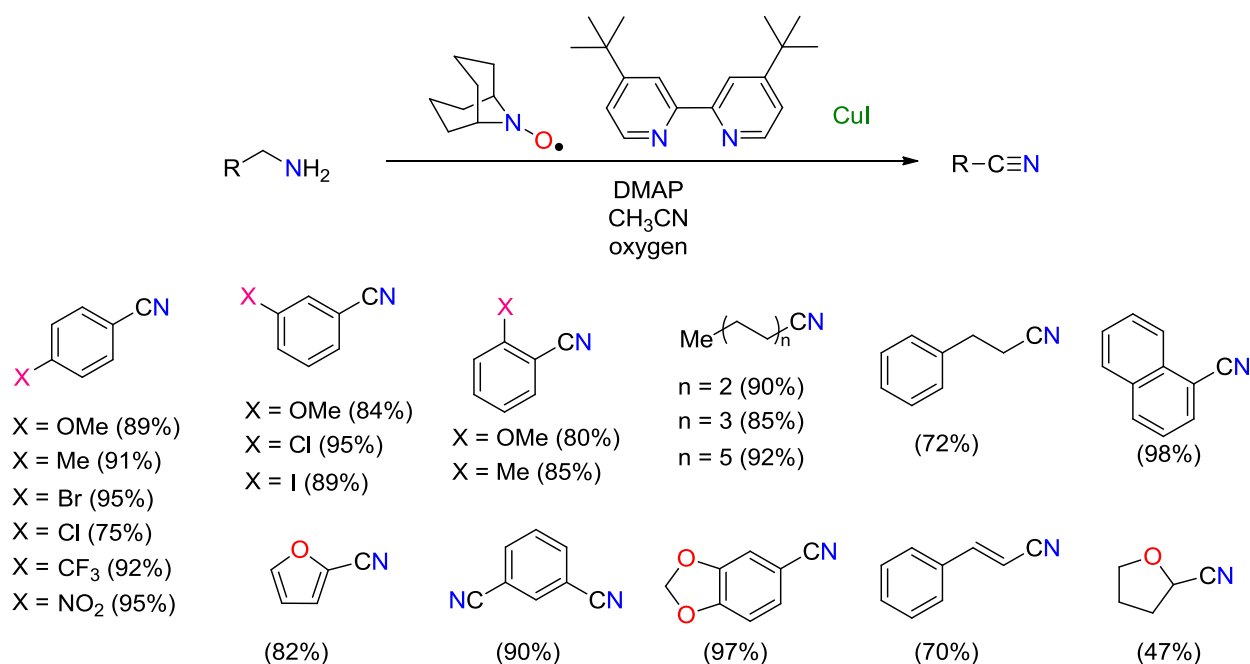
The mechanism proposed to account for the formation of homocoupled imines and nitriles is shown in Scheme 2-11. Apparently, under conditions employed by Huang et al.³⁴ the coupling of the aldimine intermediate with the amine starting material is more rapid than is the oxidation of the aldimine to a nitrile. These observations suggest that modification of such a system might be useful for the oxidation of amines to nitriles.



Scheme 2-11

In 2013, Kim and Stahl published the first report of a catalytic approach for the selective oxidation of primary amines to nitriles.³⁵ After extensive screening of reaction conditions an approach similar to Kanai and coworkers³³ was developed allowing for the formation of nitriles in good to excellent yield (Scheme 2-12). The highest yields of nitrile were obtained when using 5 mol % of each of the following: CuI, 4,4'-*t*-Bu₂bipy, and ABNO in the presence of 10 mol % DMAP in acetonitrile solvent. Reactions were allowed to stir at room temperature under an atmosphere of oxygen, the secondary oxidant, for 15 h. Overall, this process consumes inexpensive molecular oxygen.

Analysis of the oxygen uptake revealed a 1:1 ratio of molecular oxygen to amine substrate consistent with the required four-electron oxidation to the nitrile product. The authors note that the amount of homocoupled imine product is minimal and ¹H NMR analysis revealed the largest concentration of such product was formed during the initial stages of oxidation when the concentration of amine substrate is greatest. Additional control experiments indicated that nitrile formation resulted from the direct oxidation of an aldimine intermediate and did not involve a homocoupled imine intermediate.



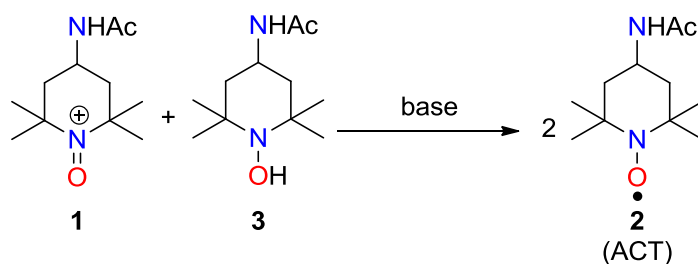
Scheme 2-12

2.2 Stoichiometric Oxidation of Primary Amines to Nitriles Using an Oxoammonium Salt³⁶

The fact that nitroxide-based catalytic systems offer a selective means to oxidize primary amines to nitriles led us to investigate the possibility that a stoichiometric amount of an oxoammonium salt would effect the same transformation in the absence of any transition metals or tailored ligands. The oxoammonium salt chosen for the investigation was 4-acetamido-2,2,6,6-tetramethylpiperidine-1-oxoammonium tetrafluoroborate (Bobbitt's salt, **1**). As described earlier, **1** is commercially available or it may be economically synthesized in multimolar quantities with little effort.³⁷

During initial experiments, **1** was added directly to a ~ 2 M solution of benzylamine in methylene chloride. A highly exothermic reaction ensued with an immediate color change from the initial yellow color of the oxoammonium salt to dark red. ¹H NMR analysis of the reaction mixture revealed the presence of benzonitrile, benzaldehyde, and *N*-benzylidenebenzylamine. It was also noted that the oxoammonium salt (**1**) was reduced to the corresponding nitroxide, 4-acetamidoTEMPO (or ACT, **2**). The formation of the nitroxide (**2**) strongly suggested a comproportionation of the oxoammonium salt (**1**) with

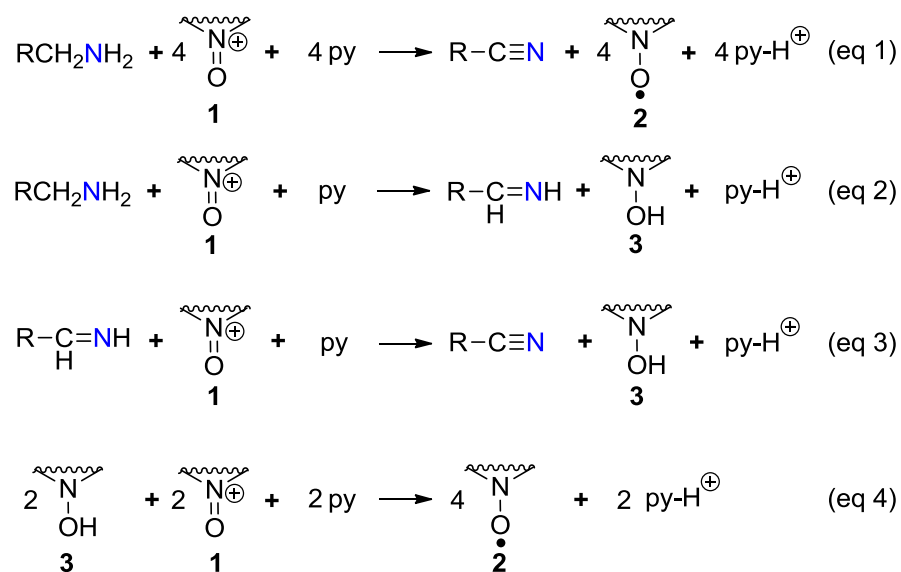
the hydroxylamine (**3**) as described previously in Chapter 1-3. The process is redrawn in Scheme 2-13, and is known to involve a base that deprotonates **3**, which then undergoes a SET with an equivalent of **1**, to produce two molecules of **2**. Clearly, since the formation of **2** is observed as a result of the oxidation, the amine substrate was acting as a base, and, since protonated amines are resistant to oxidative processes;^{1c} this presented a problem and was evidenced by the low overall yield of nitrile product. Addition of an excess of pyridine as an external base, which is resistant to oxidation by oxoammonium salts, alleviated this problem and ensured the amine substrate would remain as the free base allowing for complete oxidation. Unlike the well-known oxidation of alcohols which proceed under neutral, slightly acidic, or basic conditions, the oxidations of amine substrates in the absence of a transition metal seem to be limited to basic conditions as the substrates function as a base.



Scheme 2-13

Since the oxidation proceeds under basic conditions, the conversion of primary amines to nitriles, will require a superstoichiometric amount of **1**, and the overall oxidation is depicted in Scheme 2-14, eq 1. Two molar equivalents of **1** are required for the stepwise oxidation of the amine to an aldimine (Scheme 2-14, eq 2) and then to the nitrile (Scheme 2-14, eq 3). However, in the presence of base, the oxoammonium salt (**1**) and the hydroxylamine (**3**) comproportionate (Scheme 2-14, eq 4) to give two molar equivalents of nitroxide (**2**). Thus, a total of four molar equivalents of **1** are required for the transformation and the product mixture consists of nitrile, pyridinium tetrafluoroborate, and nitroxide (**2**). Although only four molar equivalents of pyridine would seem to be required for the transformation, an excess of pyridine was used so as to avoid protonation of the amine substrate (Scheme 1-15). The superstoichiometric requirement of oxoammonium salt, however, does not diminish the utility of the

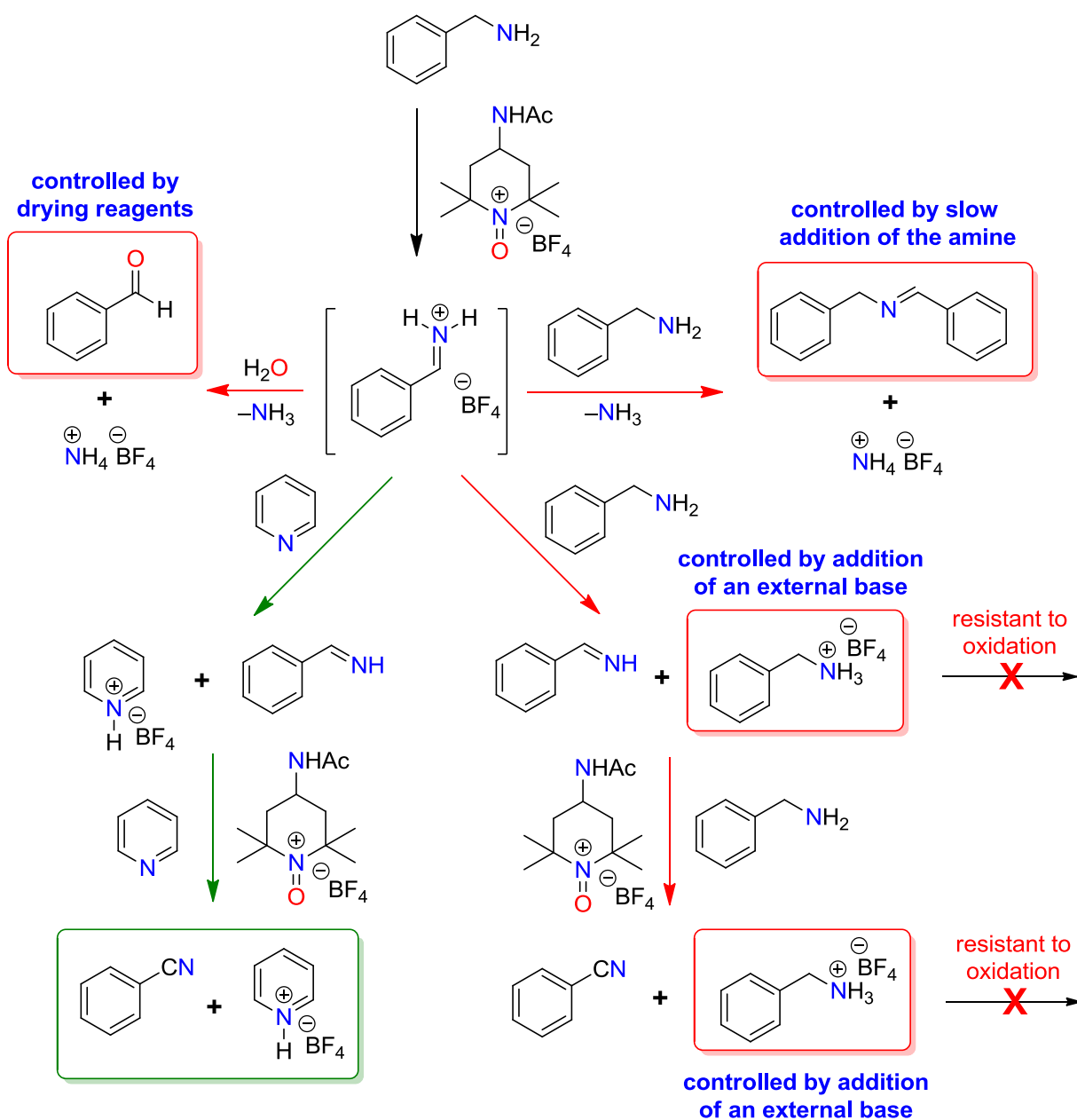
method as the reduced oxidant (**2**), a stable nitroxide, may be recovered with 70–80% efficiency, and recycled by using commercial bleach to regenerate the oxoammonium salt (**1**).³⁷



Scheme 2-14

Controlling the selectivity of the oxidation presented a challenge (Scheme 2-15). As Semmelhack,¹⁵ Kerton,³² and Stahl³⁵ all noted, the formation of a homocoupled imine ($\text{RCH}=\text{NCH}_2\text{R}$) during the oxidation of a primary amine is due to a transamination process involving loss of ammonia. Not surprisingly, Stahl³⁵ noted that the formation of the homocoupled imine was greatest at the onset of the reaction when the concentration of amine substrate was greatest. Control experiments demonstrated that the homocoupled imine does not react with **1**.

Our solution to the rapid formation of homocoupled imine during the oxidation of primary amines was a simple one: slow addition of the amine substrate to the dilute oxidation mixture to ensure the concentration of amine substrate would be low, allowing for the second oxidation of the aldimine intermediate to proceed prior to the transamination process. An addition rate of 20 mL / h was found to be appropriate for the oxidation of relatively reactive amines, while a slower rate of 15 mL / h was employed for the oxidation of less reactive substrates such as aliphatic amines.



Scheme 2-15

The last remaining hurdle was to maximize the formation of nitrile product and prevent hydrolysis of the aldimine intermediate (Scheme 2-15). To minimize adventitious water within the reaction media, pyridine and methylene chloride were thoroughly dried over calcium hydride and distilled prior to use. The oxoammonium salt was dried in a vacuum oven at 50 °C overnight prior to use, as failure to maintain an anhydrous reaction medium led to large quantities of aldehyde being isolated.

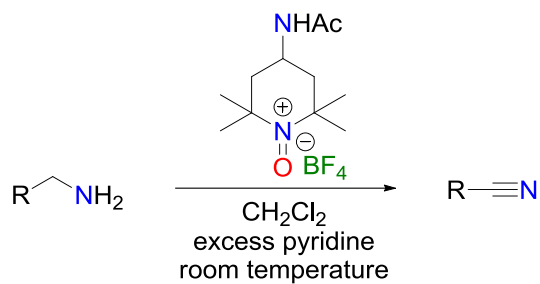
When present, any aldehyde byproduct can be removed by treatment of the crude product mixture with a commercially available aldehyde scavenger such as Silabond Amine[®].

Oxidation of primary amines to nitriles using **1** is accomplished as follows: slow addition (syringe pump; 15 - 20 mL / h) of an approximately 0.5 M solution of the amine in dry methylene chloride to a stirred slurry of 4 molar equivalents of **1** in dry methylene chloride (150 mL per 10 mmol of amine) containing 8 molar equivalents of dry pyridine followed by stirring the reaction mixture at room temperature or at gentle reflux under an atmosphere of nitrogen for a period of time. A simple extractive workup affords essentially pure nitriles, without the need for chromatographic purification, in good to excellent yield. The results are summarized in Table 2-4 and demonstrate that the oxidation protocol is a robust one.

Benzylic and allylic amines are oxidized more quickly than aliphatic amines; typically 12 h at room temperature for benzylic amines and 24 – 36 h at room temperature for aliphatic amines. Benzylic amines bearing strongly electron-withdrawing substituents are, however, oxidized rather slowly (Table 2-4, entries 7 and 9). Sluggish oxidations may be accelerated, with little loss in yield, by simply heating the reaction mixture at gentle reflux (Table 2-4, entries 9, 13 and 14).

In an effort to gain some insight into the mechanism of the oxidation, the reaction was studied computationally³⁸ at the B3LYP/6-311+G* level both for the optimizations and for calculation of the thermal corrections; all of the following data are for 298 K. The calculated results are of course for the gas phase, but they would be expected to reasonably represent the trend in energies for the solution phase. It is very difficult to calculate free energies in solution since the major thermal correction for the-gas phase results from translation, which in solution becomes diffusion a more difficult phenomenon to model. The oxidation was modeled using ethylamine as the substrate and the 2,2,6,6-tetramethylpiperidine-1-oxoammonium cation (TEMP=O⁺) as the oxidant. The results of these studies are summarized diagrammatically in Figure 2-3.

Table 2-4



entry	nitrile	time, ^b (h)	isolated yield, ^c (%)
1		12	92
2		12	93
3		12	86
4		12	90
5		12	86
6		12	73
7		24	89
8		12	87
9		24 ^d	75 ^d
10		12	90
11		14	91
12		14	92
13		36, 14 ^d	93, 88 ^d
14		24, 12 ^d	95, 92 ^d
15		24	84

^aAll reactions were conducted on a 10 mmol scale. ^bTime reaction mixture was stirred at room temperature or reflux. ^cIsolated yield of chromatographically pure product. ^dReaction mixture was heated at gentle reflux.

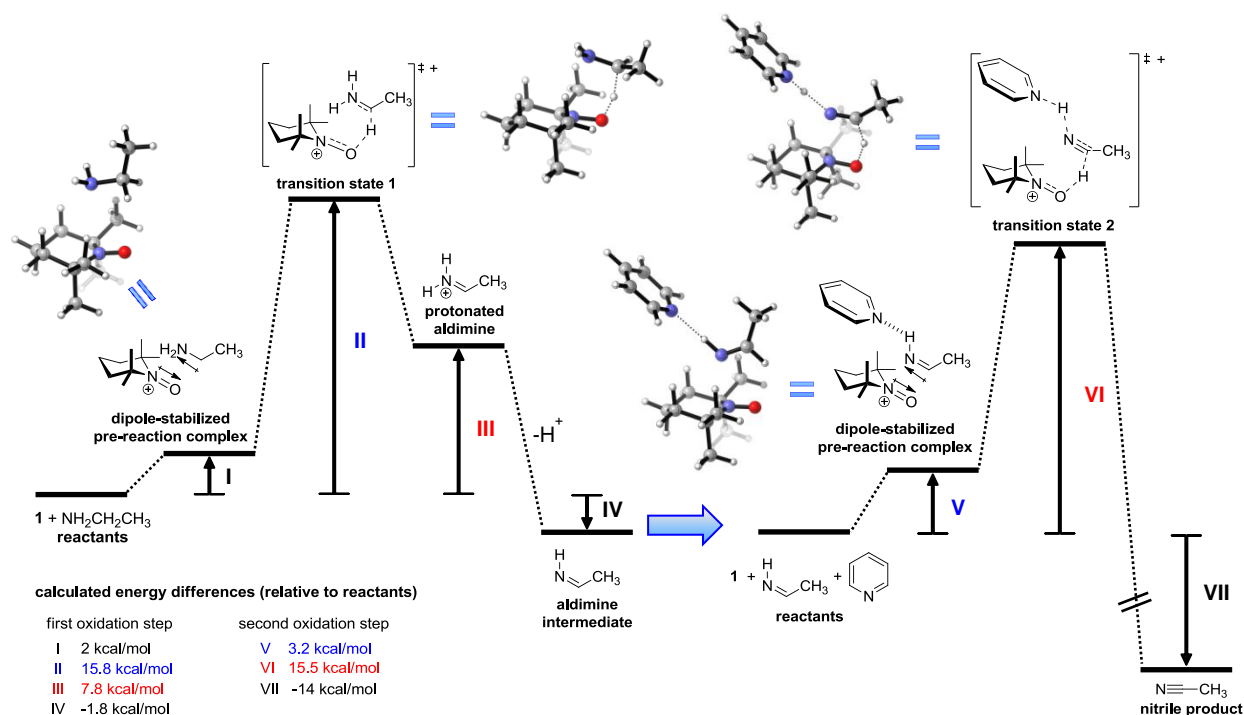


Figure 2-3

The oxoammonium cation was found to form an intermediate dipole-stabilized pre-reaction complex with the amine ($\Delta G^\circ = 2$ kcal/mol). This was followed by the first oxidation step involving transfer of a hydride from the α -carbon of the amine to the oxygen of $\text{TEMP}=\text{O}^+$ and formation of a $\text{C}=\text{N}$ bond. The transition state for this process had one imaginary frequency ($1047i$ cm^{-1}) and an activation free energy of $\Delta G^\ddagger = 15.8$ kcal/mol relative to the reactants. The product, the protonated aldimine, was less stable than the reactants by $\Delta G^\circ = 7.8$ kcal/mol but, with transfer of the acidic proton to pyridine, the product aldimine and pyridinium cation are more stable than the reactants by $\Delta G^\circ = -1.8$ kcal/mol.

The second step of the oxidation was initially modeled by computing the activation energy for hydride transfer from the α -carbon of the aldimine to the oxygen of the oxoammonium cation. This reaction leads to a high $\Delta G^\ddagger = 31.8$ kcal/mol because it results in a high energy protonated acetonitrile product. Indeed, the latter is calculated to transfer a proton to pyridine with $\Delta G^\circ = -35.5$ kcal/mole. Clearly, pyridine must participate in the oxidation step. This was studied by including pyridine in the reaction of $\text{TEMP}=\text{O}^+$ with the aldimine. Gratifyingly, this three component situation leads to a pre-reaction complex ($\Delta G^\circ = 3.2$ kcal/mole relative to reactants) and a more reasonable activation free energy

of $\Delta G^\ddagger = 15.5$ kcal/mol relative to the three reactants. This transition state had one imaginary frequency ($1016i$ cm⁻¹). The overall oxidation of the aldimine to the neutral nitrile was computed to be exothermic by $\Delta G^\circ = -14$ kcal/mole.

The mechanism suggested by these computational studies is analogous to that thought to be responsible for the oxidation of alcohols by the oxoammonium cation in neutral or acidic solution,³⁹ although the reaction proceeds under basic conditions. Both oxidations involve, as the rate-limiting step, transfer of a hydride from the substrate to the oxidant. The development of a partial positive charge on the α -carbon of the amine in the course of the oxidation nicely accounts for the fact that benzylic amines bearing electron-withdrawing substituents react more slowly than those bearing electron-donating groups. As mentioned above, the oxidation of primary amines to nitriles only proceeds under basic conditions; therefore, the reaction mechanism most closely resembles the H-bonding mechanism proposed for the oxidation of alcohols in the presence of pyridine bases.⁴⁰

The conversion of a primary amine to a nitrile using oxoammonium salt **1** is colorimetric in nature and the progress can be monitored based on the following observable changes (Figure 2-4). The initial slurry of dichloromethane, **1**, and pyridine is bright yellow in color as shown in Figure 2-4a. As the amine is added and the reaction proceeds, the color darkens, and becomes light orange after ~ 20 minutes as shown in Figure 2-4b. The hydroxylamine byproduct, **3**, in the presence of base undergoes comproportionation with another equivalent of **1** to generate nitroxide **2**, which exhibits an orange-to-wine-red color in dichloromethane solution (Figure 2-4c; after 1 h). The reaction is deemed complete when the solution appears dark wine-red in color, and the white precipitate of pyridinium tetrafluoroborate lacks the yellow color of **1**. Figure 2-4d shows the appearance upon completion of the reaction (12–36 h).



Figure 2-4a



Figure 2-4b

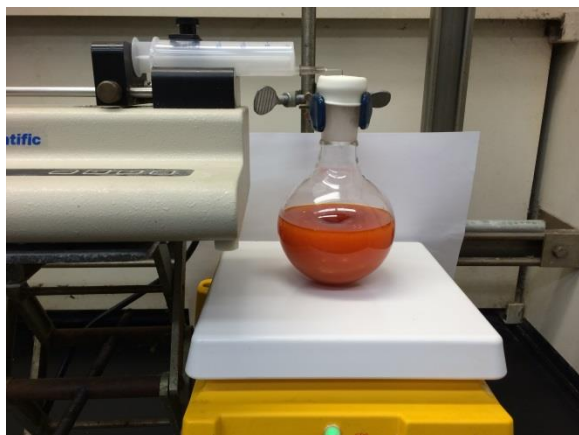


Figure 2-4c

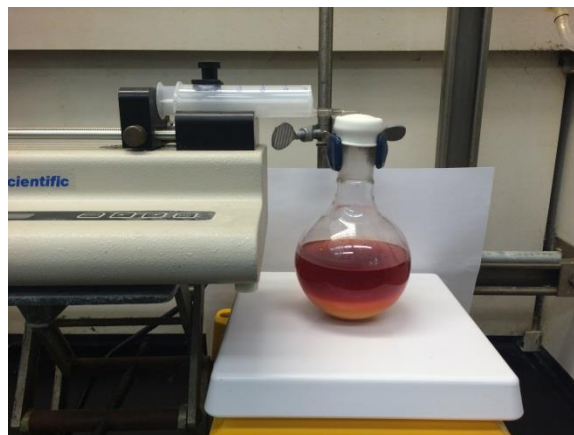
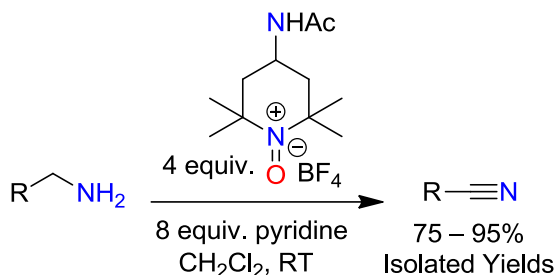


Figure 2-4d

In summary, the oxidation of primary amines at room temperature using oxoammonium salt **1** in methylene chloride – pyridine provides an experimentally simple, mild, and efficient method for the synthesis of nitriles. Moreover, the progress of the oxidation is easily followed visually.

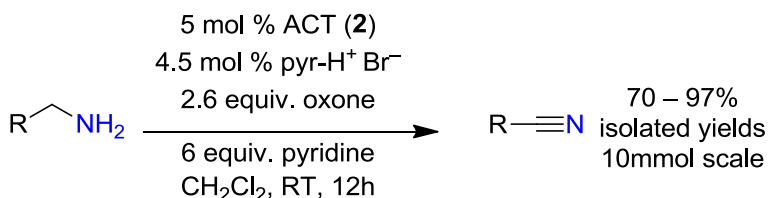
2.3 Development of a Metal-Free, Catalytic Oxidation of Primary Amines to Nitriles⁴¹

The chemistry described in Section 2.2 offers a facile, metal-free method for the oxidation of primary amines to nitriles using a stoichiometric amount of oxoammonium salt Scheme 2-16. While ideal for small-scale applications, this approach requires 4 molar equivalents of the oxoammonium salt and is impractical for large-scale syntheses.



Scheme 2-16

Using the findings described in Section 2.2 as a guide, it became of interest to develop a more practical method for the oxidation of amines to nitriles that would require only a catalytic amount of an oxoammonium cation precursor and an inexpensive, environmentally-benign terminal oxidant. Recent work by Stahl and coworkers demonstrates that the oxidation of amines to nitriles may be accomplished catalytically using oxygen as the terminal oxidant, but the process requires a ligated transition metal and a nitroxyl catalyst.^{35, 31a} Other catalytic transformations of this nature also require a transition metal catalyst.^{25–30}



Scheme 2-17

This section describes a metal-free, catalytic system for the conversion of primary amines to nitriles at room temperature that involves generation of an oxoammonium cation via coupled catalytic cycles. The oxidation, summarized in Scheme 2-17, employs the commercially available 4-acetamidoTEMPO nitroxide catalyst (ACT, **2**), environmentally benign Oxone[®] as the terminal oxidant, along with a catalytic amount of pyridinium bromide and excess pyridine as a base. Figure 2-5 illustrates relevant catalysts and oxidants used. As detailed below, the oxidation is operationally simple and pure nitrile product is isolated in good to excellent yield by filtration and removal of the solvent.

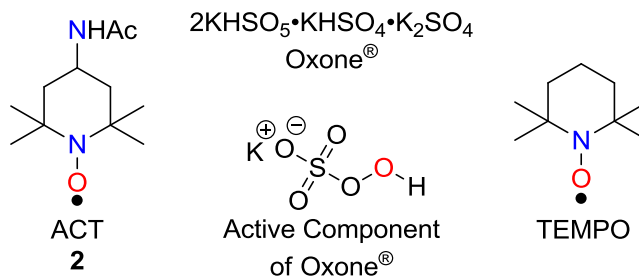
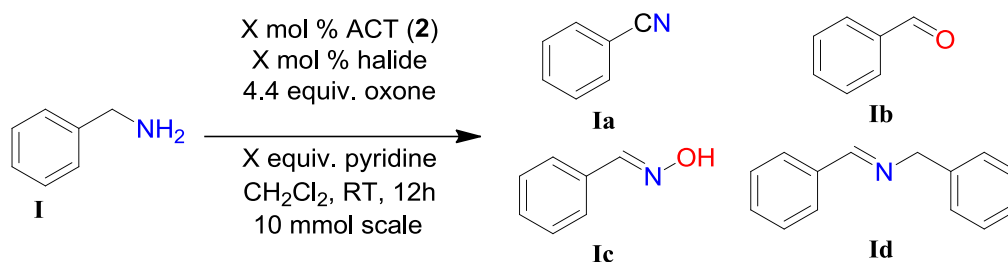


Figure 2-5

Initial efforts focused on identifying a suitable terminal oxidant to generate the active oxoammonium salt without negatively impacting the sensitive amine substrate. We were intrigued by Bolm and coworkers' use of the inexpensive triple salt, Oxone[®], with the widely used nitroxide radical, TEMPO, to oxidize alcohols catalytically in the presence of a halide source.⁴² While Bolm's chemistry offers a cheap and efficient route to generate an oxoammonium salt, oxone is known to react with a variety of substrates including amines.⁴³ Additionally, the oxone/TEMPO system is multifaceted as it relies on the *in situ* generation of hypobromous acid, which is responsible for the turnover of the TEMPO catalyst as reported by Rychnovsky and coworkers.⁴⁴ Exploratory experiments with benzylamine (**I**), chosen as a model substrate, were performed as highlighted in Table 2-5.

When **I**, as a 0.5 M solution in CH₂Cl₂, was added at a rate of 10 mL/h to a stirred slurry of oxone in CH₂Cl₂ and allowed to stir for 12 h at room temperature, no change was observed (Table 2-5, entry 1). Not surprisingly,⁴⁵ when the same reaction was conducted under basic conditions in the presence of 8 equivalents of pyridine, substantial amounts of pyridine N-oxide resulted; additionally, approximately half of the starting material, **I**, was consumed and the formation of **Ic** was observed (Table 2-5, entry 2). The introduction of tetrabutylammonium bromide into the reaction mixture (Table 2-5, entry 3) resulted in the formation of a small amount of **Id** likely formed by a bromination of the amine and subsequent elimination under the basic conditions to generate an aldimine, which rapidly undergoes reaction with another equivalent of **I** with loss of ammonia to generate **Id**.¹ From this observation, it quickly became apparent that the bromide additive must be controlled in some manner to prevent this detrimental side reaction.

Table 2-5



Entry	Halide Source	Pyridine	ACT (2)	Result
1 ^a	None	None	None	No change in I
2 ^a	None	8 equiv.	None	Equal amounts of I and Ic observed in addition to pyridine N-oxide
3 ^a	9 mol % <i>n</i> -Bu ₄ N ⁺ Br ⁻	8 equiv.	None	I remained, pyridine N-oxide, and ~8% of Id was detected
4 ^b	5 mol % <i>n</i> -Bu ₄ N ⁺ Br ⁻	8 equiv.	10 mol %	87% isolated yield of Ia with 1% Ib
5 ^b	4.5 mol % <i>n</i> -Bu ₄ N ⁺ Br ⁻	6 equiv.	5 mol %	95% isolated yield of Ia
6	9 mol % KBr	8 equiv.	10 mol %	Failed to generate hypobromous acid
7 ^a	9 mol % KBr + 50 μL H ₂ O	8 equiv.	10 mol %	Ia along with substantial amounts of Ib and Id
8 ^b	4.5 mol % pyridine•HBr	6 equiv.	5 mol %	92% isolated yield Ia

^a The crude reaction mixture was analyzed by GC/MS both before and after extraction with 1M NaOH to ensure all basic substrates were detected. ^b Isolated yields on a 10 mmol scale.

While control experiments revealed competitive processes, the addition of ACT resulted in a faster, more selective oxidation to access nitriles. The use of a slight molar excess of ACT relative to the tetrabutylammonium bromide effectively sequesters the bromide in the generated oxoammonium salt, reducing the likelihood of bromination of the amine substrate. These modifications resulted in the formation of benzonitrile (**Ia**) in an 87% isolated yield, accompanied by ~1% of benzaldehyde (**Ib**) (Table 2-5, entry 4) likely due to the presence of residual water. However, when strictly anhydrous conditions

were employed the reaction failed to proceed. Apparently, a catalytic amount of water is necessary to solubilize a small portion of the oxone. The use of commercially available reagent-grade CH_2Cl_2 without any additional drying was sufficient for this purpose, and any aldehyde by-product (typically less than 3%) is easily removed upon work-up.⁴⁶ Decreasing the catalyst loading to 5 mol % ACT, 4.5 mol % tetrabutylammonium bromide, and 6 molar equivalents of pyridine relative to the starting amine resulted in a slight increase in the isolated yield of (**1a**) (Table 2-5, entry 5). Owing to the extremely hygroscopic nature of tetrabutylammonium bromide, it was necessary to constantly re-dry the bromide to prevent substantial amounts of water from being introduced into the reaction mixture resulting in the formation of unwanted aldehyde. As a practical matter, complete removal of the tetrabutylammonium bromide upon completion of the reaction was problematic. When anhydrous potassium bromide was used, the system failed to generate hypobromous acid, and the intentional addition of a small amount of water to help solubilize the bromide resulted in the loss of selectivity (Table 2-5, entries 6–7). Pyridinium bromide was found to be optimal for our purposes (Table 2-5, entry 8). In addition to complementing our choice of base, the salt is easily prepared in anhydrous form.⁴⁷

Oxidation of primary amines to nitriles under our catalytic conditions is achieved as follows: Addition of a 0.5 M solution of amine substrate in CH_2Cl_2 at a rate of 10 mL/h via syringe pump to a stirred slurry of 4.4 molar equivalents of oxone,⁴⁸ 5 mol % of ACT (**2**), 4.5 mol % of pyridinium bromide, and 6 molar equivalents of pyridine in 100 mL of CH_2Cl_2 . While most reactions were completed within a few hours after the conclusion of amine addition to the reaction mixture, product isolation was substantially easier when reaction mixtures were stirred at room temperature for 12 h.⁴⁹ Passage of the crude reaction mixture through a small bed of silica gel, and removal of the solvent, afforded pure nitrile products (Table 2-6).

Table 2-6

$ \begin{array}{c} \text{5 mol \% ACT (2)} \\ \text{4.5 mol \% pyr-H}^+ \text{ Br}^- \\ \text{2.6 equiv. oxone} \\ \text{R-CH}_2\text{NH}_2 \xrightarrow{\text{6 equiv. pyridine}} \text{R-C}\equiv\text{N} \\ \text{CH}_2\text{Cl}_2, \text{RT, 12h} \end{array} $					
Entry ^a	Nitrile	Yield ^b	Entry ^a	Nitrile	Yield ^b
1		92	12		97
2		91	13		92
3		86	14		92
4		86	15		98, 99 ^d
5		88	16		58
6		86	17		88
7		89	18		89
8		86	19		93
9		98	20		86
10		72, 89 ^c	21		88
11		90	22		98

^a All reactions were carried out on a 10 mmol scale at RT and isolated yields refer to the analytically pure nitrile products after isolation from the reaction mixture as described in the Experimental Section. ^b Isolated yields on a 10 mmol scale. ^c This reaction was run with 10 mol % ACT (2) and 9 mol % of pyridinium bromide. ^d This reaction was run on a 50 mmol scale as detailed in the Experimental Section.

The oxidation works well for a variety of electron-deficient and electron-rich benzylamines affording isolated yields in the range of 86–97% (Table 2-6, entries 1–9). Oxidation of cinnamylamine under the general reaction conditions resulted in a moderate isolated yield of 72% (Table 2-6, entry 10). However, upon increasing the amount of ACT (**2**) and pyridinium bromide to 10 mol % and 9 mol %, respectively, the reaction proceeded efficiently resulting in an 89% isolated yield of cinnamionitrile (Table 2-6, entry 10). Similarly, when the alkene moiety is removed from conjugation and is placed in a terminal location, the yield also suffers (Table 2-6, entry 16) due perhaps to reactions with electrophilic bromine species⁵⁰ or polymerization in the presence of the radical catalyst.⁵¹

Small heterocycles such as thiophenes and tetrahydrofurans (Table 2-6, entries 11 & 22) are well tolerated by the general reaction conditions. Although not screened as a substrate, compounds containing a sulfur atom that does not participate in aromaticity may present problems, as oxone is known to readily oxidize sulfur substrates to sulfones and sulfoxides.⁴³ Simple aliphatic substrates (Table 2-6, entries 12–15) were oxidized to the resulting nitriles quite efficiently with isolated yields in the range of 92–98%. Oxidation of sterically congested aliphatic substrates (Table 2-6, entries 17 & 18) proceeded smoothly as well. Substrates containing an acetal functionality were oxidized in good yield without any observed hydrolysis (Table 2-6, entries 19 & 20). Additionally, an acid-sensitive *tert*-butyl-dimethylsilyl protected amino alcohol was easily converted to the corresponding nitrile in 88% isolated yield under the reaction conditions (Table 2-6, entry 21). Significantly, the reaction is easily scaled as detailed in the experimental section. The oxidation of dodecylamine on a 50 mmol scale (9.36 g) afforded the nitrile (9.18 g) in a virtually quantitative isolated yield of 99 % (Table 2-6, entry 15).

A proposed overall catalytic sequence for the oxidation is illustrated in Figure 2-6. The process involves a cascade of catalytic cycles which are intertwined. The initiating step involves generation of hypobromous acid upon reaction of pyridinium bromide with oxone. This step is analogous to one proposed for the oxidation of alcohols by the MCPBA/TEMPO⁴⁴ and oxone/TEMPO⁴²⁰ catalytic systems in the presence of bromide additives. There is likely a significant pH dependence associated with the catalytic cycle depicted in Figure 2-6. Experimentally, the pH of the oxidation is maintained within a

range of 7.5–8.5 throughout the course of the reaction. This pH range favors the formation of hypobromous acid rather than the hypobromite anion.⁵² Indeed, the presence of hypobromous acid is observed as a colorimetric change from colorless to light yellow as pyridinium bromide is added to the slurry of oxone in CH_2Cl_2 . The hypobromous acid is doubtlessly responsible for the catalyst turnover as it can undergo a single electron transfer (SET) with ACT to generate the active oxoammonium species.⁴²

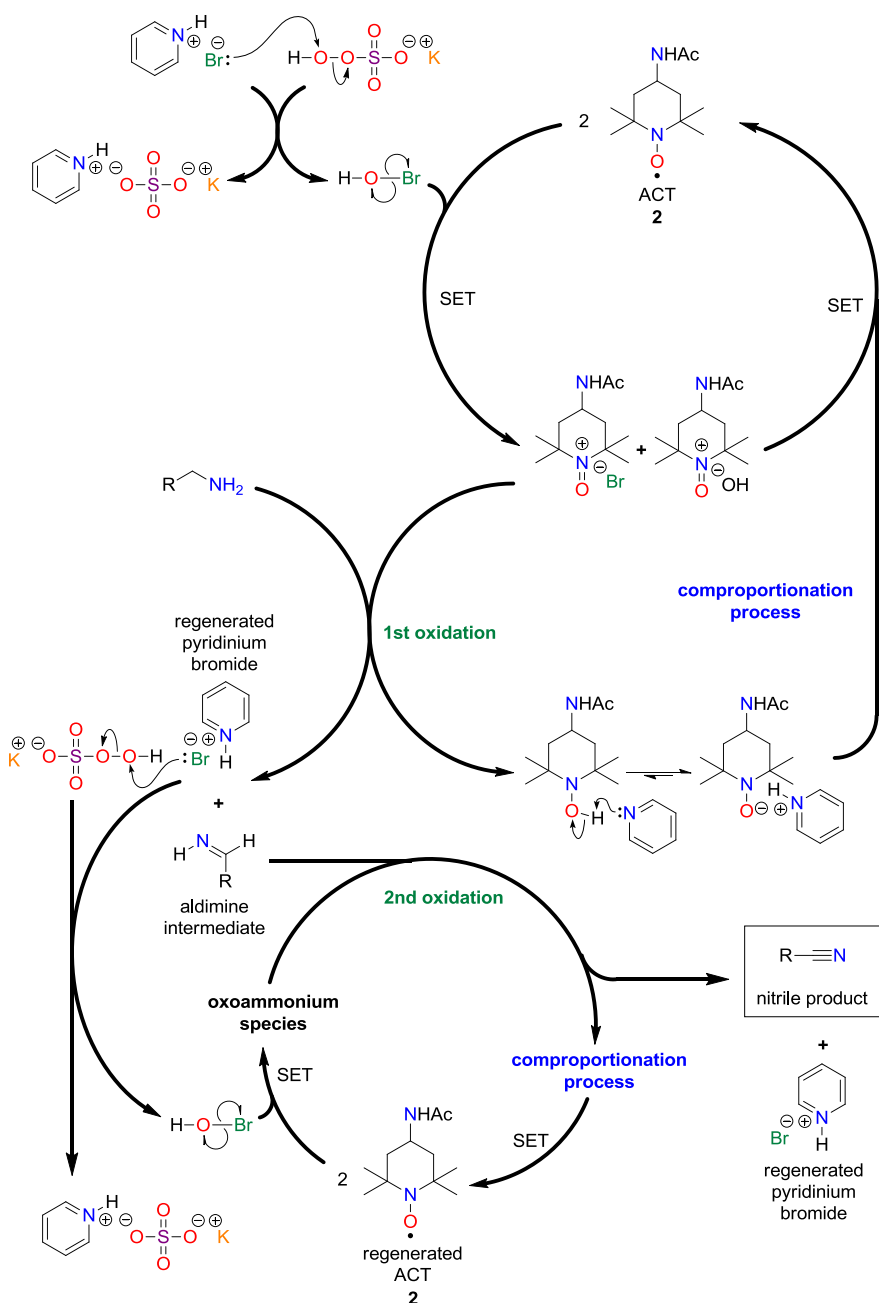


Figure 2-6

While there are a variety of counterions for the oxoammonium salt, given the different anionic species present in the reaction mixture, it is believed the bromide oxoammonium species participates in the oxidation of the amine substrate, recycling the pyridinium bromide necessary for formation of the hypobromous acid. Given the inherent acidity of oxone (pH ~4–5), a large excess of pyridine is required to establish an equilibrium in which the more basic amine substrate as well as the aldimine intermediate are not protonated. It is well-known that protonated amine salts are resistant to oxidation.⁵³

The oxoammonium cation is ultimately responsible for the oxidation of the primary amines to nitriles. A control run (Table 2-5, entry 3), in which the only reagent removed from the reaction mixture was the ACT catalyst, failed to produce the nitrile. The actual oxidation step is believed to proceed by way of a hydride transfer mechanism,³⁶ resulting in the formation of an aldimine intermediate. Two molar equivalents of pyridine are consumed in this first oxidation step, allowing for the recycling of both the pyridinium bromide and the ACT catalyst. Deprotonation of the hydroxylamine produced as a result of the first oxidative step results in a rapid single-electron transfer (SET) with another oxoammonium cation in a comproportionation process that regenerates two molecules of ACT as described explicitly earlier in this work.⁵⁴ The aldimine intermediate is further oxidized to the desired nitrile product through the same sequence of events. The stoichiometry of the overall process requires at least two molar equivalents of KHSO₅, the active component of oxone, and at least four molar equivalents of a pyridine base in the presence of a catalytic amount of ACT and pyridinium bromide.

In summary, a mild and metal-free catalytic methodology for the conversion of primary amines to nitriles in good to excellent yields is described. The inexpensive triple salt oxone is employed as an environmentally benign stoichiometric oxidant, which in the presence of a catalytic amount of pyridinium bromide controllably generates hypobromous acid *in situ*. The hypobromous acid is responsible for the turnover of a commercially available nitroxide catalyst, ACT, to an active oxoammonium cation. It is this cation which is responsible for the selective oxidation of primary amines to nitriles. The reaction is operationally simple to perform, scalable, and tolerates a wide variety of functionality.

2.4 Oxidation of Alcohols and Aldehydes to Nitriles Using an Oxoammonium Salt⁵⁵

Aside from the direct oxidation of primary amines to nitriles, described in sections 2.3 and 2.4 above, another useful method that allows for the generation of the nitrile functionality is through the oxidation of primary alcohols and aldehydes in the presence of a nitrogen source. Typical approaches to afford nitriles rely on the reactivity of hydroxylamine upon exposure to an aldehyde substrate to furnish an oxime, which through dehydration produces the desired nitrile.⁵⁶

In collaboration with Leadbeater and co-workers, the initial goal was to develop a protocol for the amidation of aldehydes employing hexamethyldisilazane (HMDS) as the nitrogen source using an approach similar to that used to accomplish oxidative esterification of an aldehyde with hexafluoroisopropanol.⁵⁷ During a screening of various bases for the stoichiometric oxidation of benzylamine by an oxoammonium salt and work described in Section 2.2, it was noted that amine bases lacking an α -hydrogen, such as 2,2,6,6-tetramethylpiperidine and *tert*-butylamine, failed to react with the oxoammonium salt. On this basis, it was envisioned that using the method developed for oxidative esterification⁵⁷ (Figure 2-7; eq. 1), it should be possible to effect oxidative amidation with HMDS as it does not undergo side reactions with the oxoammonium cation, and upon acidic work-up the removal of the trimethylsilyl group(s) would furnish a primary amide (Figure 2-7; eq. 2). Aqueous ammonia as the source of nitrogen would be ideal, however oxoammonium salts rapidly react with ammonia as described later in this work.

A test reaction was conducted using *p*-anisaldehyde as a substrate in pyridine solvent with two equivalents of HMDS and Bobbitt's salt (**1**). Upon addition of **1** to the reaction mixture, a deep green color developed that persisted for 30–45s, then faded to the initial light yellow color typical of most oxoammonium salt oxidations. The origin of the green color is not known, and it is only observable when strong electron-donating substituents are present on the aryl ring. After 3–5 minutes the reaction mixture begins to warm and quickly undergoes a yellow \rightarrow red color change; the result of the reduction of **1** to produce the corresponding nitroxide **2**. This observation demonstrated that an oxidation had occurred. However, upon GC-MS and ¹H NMR analysis of the product mixture, it was apparent that the sole

product was not *p*-methoxybenzamide, but was *p*-methoxybenzonitrile (Figure 2-7; eq. 3). This serendipitous discovery allowed for the development of an efficient, general protocol for the oxidative conversion of alcohols and aldehydes to nitriles using a recyclable oxoammonium salt oxidant.

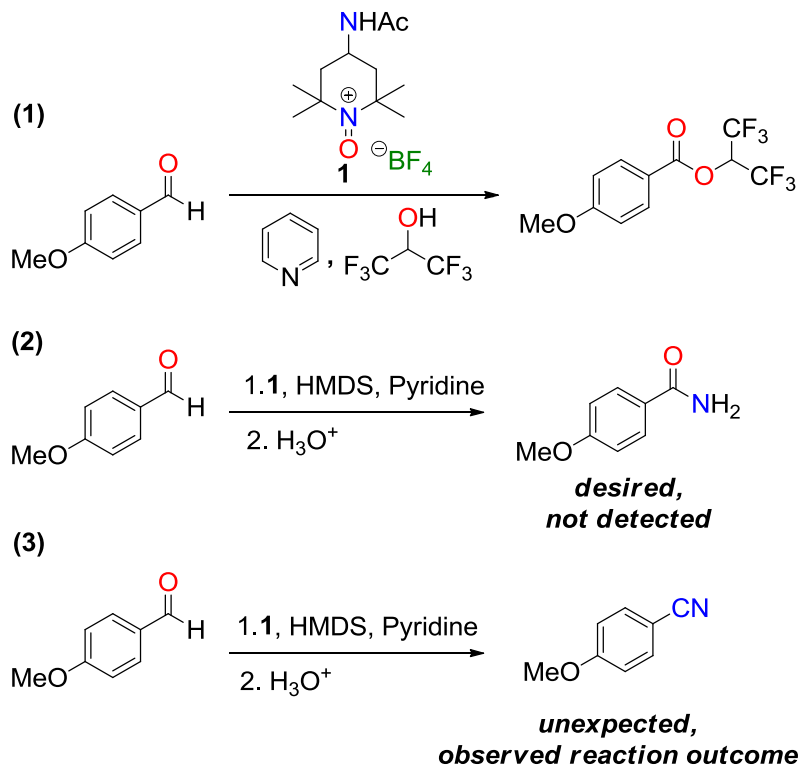


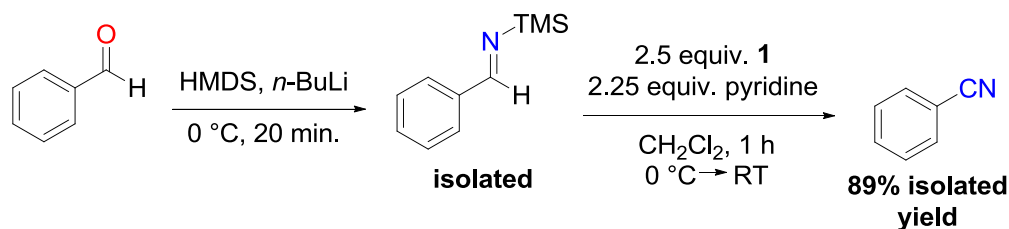
Figure 2-7

To move forward with the development of such a methodology, the reaction conditions were first optimized. The exothermic nature of the reaction was easily controlled, by conducting the reaction in CH_2Cl_2 , which was selected due to the favorable solubility properties of oxoammonium salts in this solvent. By diluting the reaction mixture, no appreciable increase in reaction time was observed and using the solvent as a “thermal sink”, the exotherm was controlled and undetectable at an aldehyde concentration of 0.5 M.

Additionally, it was found that pyridine was not essential for the reaction, unlike oxidative esterification reactions with oxoammonium salts which fail to proceed in the absence of pyridine.⁴⁰ This observation demonstrated that pyridine did not play a role in the mechanism of oxidation of aldehydes to nitriles. The stoichiometry of the reaction was explored as well. Since the reaction proceeded under

basic conditions, it was necessary to use twice as much oxidant due, as noted above, to the known comproportionation of oxoammonium salt reagents under basic conditions. Thus, when one molar equivalent of **1** is employed in the presence of an excess of HMDS (3 molar equiv.), the resulting nitrile product is predicted to form in a 50% yield due to the known comproportionation of **1** and **3** under basic conditions and with remainder of the mixture to contain the starting aldehyde. When such a reaction is conducted, the nitrile product does indeed form in a 50% yield, however the remainder of the starting aldehyde has been consumed resulting in the formation of a second product. If 0.5 molar equivalents of **1** are employed, 25 % conversion to the nitrile product was observed and an equal amount of a second product was detected to form by ¹H NMR analysis of the crude reaction mixture. This was later identified as an *N*-(trimethylsilyl)imine formed from the reaction of HMDS with the aldehyde. The formation of the silylated imine suggested that *N*-(trimethylsilyl)imine must be a reaction intermediate. The formation of such a *N*-(trimethylsilyl)imine intermediate is likely to allow for the reaction to be driven to completion, as the oxidation of imines by oxoammonium salts to furnish nitriles was computed by Wiberg to be highly exothermic in nature, (−14 kcal/mol)³⁶. These two observations offered evidence that the reaction proceeds through the oxidation of an imine intermediate as reported in Section 2.2 and Section 2.3 of this work.

Further evidence of the intermediacy of a silylimine is provided by the fact that when benzaldehyde *N*-(trimethylsilyl)imine was independently prepared, then subjected to the oxidation conditions, benzonitrile, nitroxide **2**, and trimethylsilyl fluoride were formed. The benzonitrile product was obtained in a 89% isolated yield when the oxidation was performed on a 10 mmol scale (Scheme 2-18). The same three products are observed when benzaldehyde is treated with **1** in the presence of HMDS in dichloromethane solvent. When the perchlorate analogue⁵⁸ of **1** was used for the oxidation, hexamethyldisiloxane was the observed by-product and no trimethylsilyl fluoride was observed.



Scheme 2-18

The role of the HMDS was investigated, and when 1 molar equivalent of HMDS and 2 molar equivalents of **1** were employed, only 50% conversion to the nitrile product occurred, with the remainder being the starting aldehyde and **1**; no intermediate imine was detected. When 2 or more molar equivalents of HMDS were employed full conversion to the nitrile product occurred; the ideal amount of HMDS was determined to be 2.5 molar equivalents relative to starting aldehyde.

These experimental results allowed for a plausible reaction mechanism to be proposed. The published mechanism⁵⁵ has since been reevaluated; the proposed mechanism is shown in Figure 2-8. While the general oxidation pathway is identical in both mechanisms, there are two main differences: a) the formation of the nitrile product is more likely a one-step concerted process rather than the published two-step process; and, b) the production of boron trifluoride as a by-product is unlikely.

It was proposed in the published mechanism⁵⁵ that the *N*-(trimethylsilyl)imine, which is formed from the reaction of the aldehyde substrate with HMDS (Figure 2-8; eq. 1), forms a nitrillium intermediate, however, as shown by Wiberg's computational investigation of the oxidation of imines³⁶, the formation of such an adduct would result in a high $\Delta G^{\ddagger} = 31.8$ kcal/mol. This activation energy is unreasonably high for such a process, thus the oxidation must allow for a one-step de-silylation process (Figure 2-8; 2) as any nitrillium intermediate is unlikely to form.

As illustrated in Figure 2-8; eq. 2, the imine intermediate likely organizes into a dipole-stabilized pre-reaction complex with the oxoammonium salt, which then undergoes a concerted de-silylation / hydride-transfer process. This process is initiated by the formation of a strong Si–F bond by attack of fluoride on silicon, which effects de-silylation promoting the hydride transfer to the oxoammonium salt and furnishing the product nitrile along with trimethylsilyl fluoride and a hydroxylamine / BF₃ complex.

This hydroxylamine / BF_3 complex likely establishes an equilibrium with the residual hexamethyldisiloxane forming an etherate with the BF_3 (Figure 2-8; eq. 3): Such a B–O coordination complex, is stronger than the B–N coordination, and results in the more stable coordination complex. When the hydroxylamine (**3**) is free from complexation with BF_3 , it would easily undergo comproportionation with another molecule of **1** to form two molecules of nitroxide **2**, since the reaction proceeds under basic conditions. The HMDS serves as the external base to promote the comproportionation process, and resulting protonated HMDS tetrafluoroborate salt either precipitates out of solution or undergoes a de-silylation process (Figure 2-8; eq. 4).

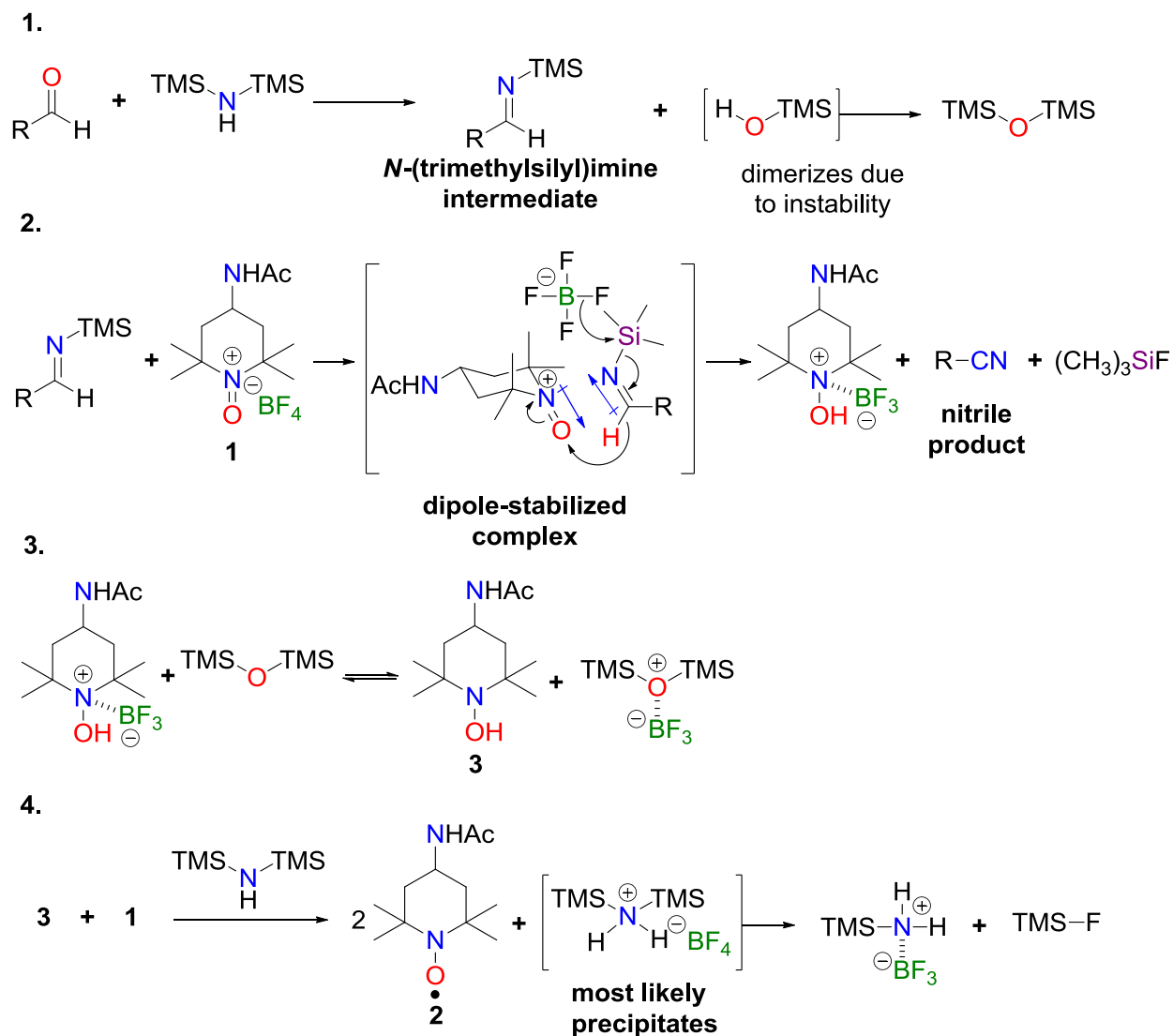


Figure 2-8

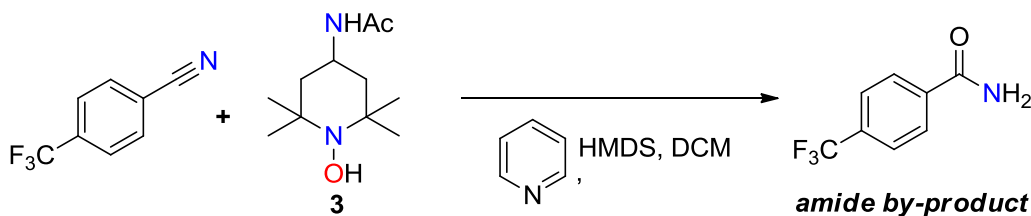
The reconsideration of the mechanism was sparked by the finding that the oxidation could be conducted in an aqueous environment. Clearly, naked BF_3 would not likely exist in water. However, the aqueous oxidation is limited as HMDS reacts with water, and many aldehyde substrates are oxidized to carboxylic acids in aqueous environments.⁵⁹ Additionally, the oxidation works with oxoammonium salts that do not contain the tetrafluoroborate anion, but the use of fluorine-containing anions is preferred as the oxidations occur at a faster rate.

Optimal reaction conditions, developed after consideration of the results of the mechanistic study, were as follows: to a 0.5 M solution of aldehyde in CH_2Cl_2 solvent was added, 2.5 molar equivalents of HMDS relative to the aldehyde starting material, 1.1 molar equivalents of pyridine,⁶⁰ followed by the addition of 2.5 molar equivalents relative to the starting aldehyde of **1** in one portion. The resulting slurry was stirred for a given period of time and monitored by ^1H NMR until full consumption of the aldehyde starting material. A small-scale reaction is worked-up through a simple extraction with an aqueous, 2 M solution of HCl to remove any basic material and the resulting nitroxide **2**. Passage through a small silica gel plug and solvent removal affords analytically-pure nitrile product in good to excellent yields (51–97%). For large scale reactions, a work-up procedure was developed to recover the nitroxide **2**; allowing for recycling of the oxidant.

The reaction is general, scalable and allows for the oxidation of both aryl and aliphatic aldehydes as evidenced by the results shown in Table 2-7. The electronic constraints of the reaction were easily evaluated with substituted benzaldehyde substrates. The oxidation tolerates both electron-rich (Table 2-7, entries 1, 2, 8, and 9) and electron-deficient derivatives (Table 2-7, entries 3–7), however, electron-deficient substrates oxidized at a much slower rate and resulted in slightly decreased isolated yields. The time required for the oxidation to reach completion increases proportionally relative to the Hammett substituent parameters: 1 h for *p*- OCH_3 (Table 2-7, entry 1; $\sigma_p = -0.28$) and 36 h for *p*-CN (Table 2-7, entry 5; $\sigma_p = 0.70$). This experimental finding offers strong evidence that the oxidation proceeds through

removal of a hydride from the substrate by **1**. When strongly electron-deficient substrates (Table 2-7, entries 4 and 5) are oxidized it is not possible to obtain complete conversion in less than 36 h using the optimized reaction conditions. Premature quenching of the reaction mixture led to hydrolysis of the intermediate imine, thus diminishing yield and furnishing the starting aldehyde as a contaminant (typically < 10% by ^1H NMR spectroscopy). This contaminant could easily be removed by simply stirring the crude reaction mixture overnight in Et_2O in the presence of a commercially available silica-bound amine-based scavenger³⁶.

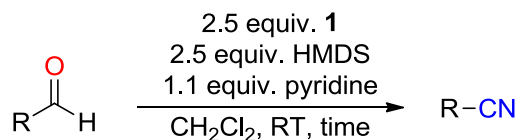
Additionally, the oxidation of electron-deficient substrates suffer from lower isolated yields as a consequence of a unique side reaction, reported by Endo and coworkers⁶¹, between the electron-deficient nitrile products and the resulting hydroxylamine **3** to afford amides (Scheme 2-19). Moreover, Endo found the side reaction is significantly accelerated under basic conditions, thus explaining the observed amide by-products and the greatly diminished yields of *p*-trifluoromethylbenzonitrile and *p*-cyanobenzonitrile (Table 2-7, entries 4 and 5). Interestingly, the steric constraints of *o*-nitrobenzonitrile prevent this side reaction from occurring to any significant extent, as an 80% isolated yield of the nitrile is obtained (Table 2-7, entry 7). This assertion is further evidenced by the fact by that *p*-nitrobenzonitrile results in large amounts of amide by-product and was not used as a substrate as a result.

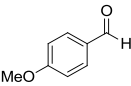
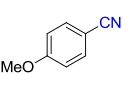
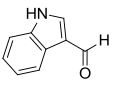
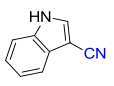
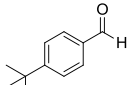
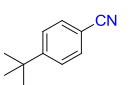
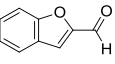
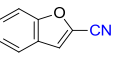
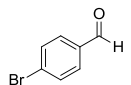
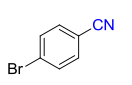
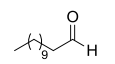
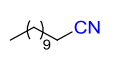
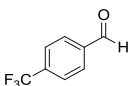
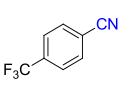
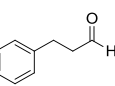
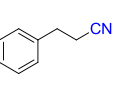
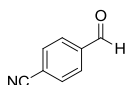
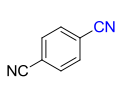
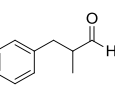
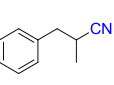
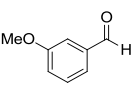
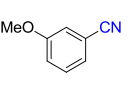
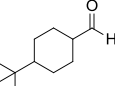
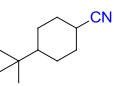
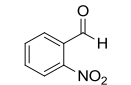
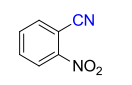
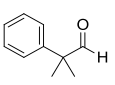
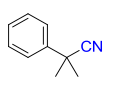
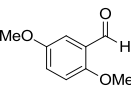
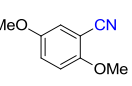
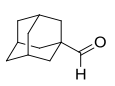
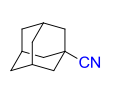
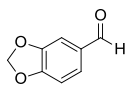
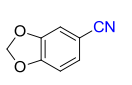
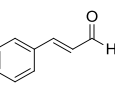
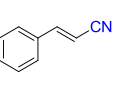
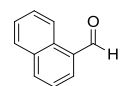
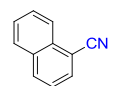
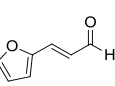
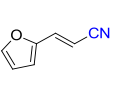
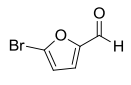
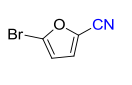
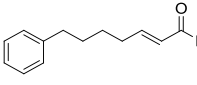
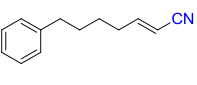
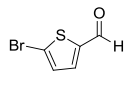
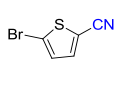
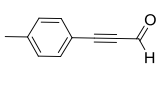
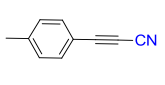


Scheme 2-19

The scope of the oxidation was further explored with polycyclic and heterocyclic substrates containing oxygen, sulfur, and nitrogen (Table 2-7, entries 10–14), which smoothly underwent oxidation to afford the respective nitriles in good yield (69–88%).

Table 2-7



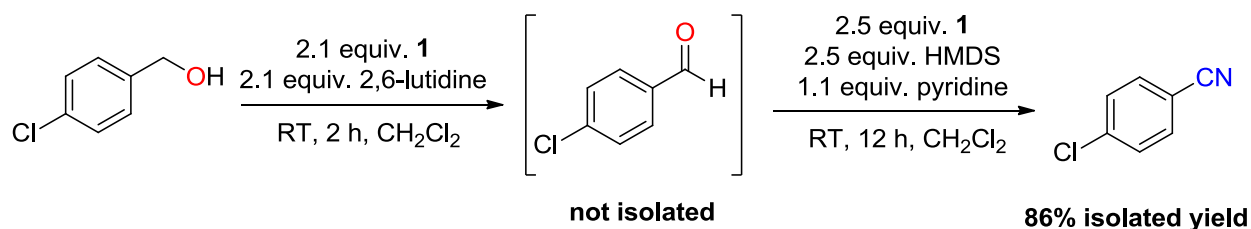
Entry ^a	Aldehyde	Nitrile	Time ^b	Yield ^c	Entry ^a	Aldehyde	Nitrile	Time ^b	Yield ^c
1			1	95 (90) ^d	13			2	67
2			4	97 (88) ^d	14			12	75
3			24	75	15			1	80
4			36	51 ^e	16			1	71 ^f
5			36	69	17			4	72
6			12	91	18			2	96
7			24	80	19			32	80
8			4	88	20			1	82
9			12	93	21			2	86
10			12	88	22			12	78 ^g
11			12	82	23			—	— ^h
12			12	69	24			1	79

^a Conditions unless otherwise noted: aldehyde in CH₂Cl₂ (10 mmol, 1 equiv., 0.5 M), HMDS (25 mmol, 2.5 equiv.), pyridine (11 mmol, 1.1 equiv), **1** (25 mmol, 2.5 equiv) ^b time in h ^c Isolated yields ^d Yield on 50 mmol scale ^e A 50:50 mixture by volume of Et₂O and CH₂Cl₂ was used as the solvent ^f HMDS was added to the reaction mixture slowly dropwise ^g Reaction was run at 0.1 M to prevent polymerization ^h Complex mixture observed.

Aliphatic aldehydes, both easily accessible and sterically hindered substrates, were tolerated under the reaction conditions (Table 2-7, entries 15–20). The straight-chain aliphatic aldehydes bearing no α -substitution were problematic; as such substrates undergo aldol condensations in the presence of silylated amines.⁶² A solution to this problem was to add the HMDS slowly to the reaction mixture resulting in fair yields of nitrile product (Table 2-7, entries 15–16).

Unsaturated aldehyde substrates which are fully conjugated are tolerated by the reaction conditions, however, competing polymerization reactions can occur and such reactions may need to be run under dilute conditions, which results in longer reaction times (Table 27, entry 22). The removal of the double bond from complete conjugation accelerates the polymerization process as a consequence of various Michael additions into the alkene.^{57,61}

The reaction is easily scalable as evidenced by the oxidation of *p*-OCH₃ and *p*-*t*-Bu benzaldehyde (Table 2-7, entries 1 and 2) on a 50 mmol scale, resulting in the formation of the nitrile product in 90% and 88% isolated yields, respectively. While the scale-up of the oxidation reactions requires large amounts of **1**, a work-up procedure has been developed to recover the nitroxide by-product **2** at the completion of the oxidation, allowing for its recycling and the regeneration of **1**.



Scheme 2-20

To expand the utility of this approach, the conversion of alcohols could be converted using **1** was investigated. Employing a two-step, one-pot procedure, it was found that this transformation could indeed be accomplished successfully (Scheme 2-20). Thus, *p*-chlorobenzyl alcohol was oxidized to *p*-chlorobenzaldehyde under basic conditions.⁶³ Subsequent addition of HMDS, pyridine, and more **1** provided the nitrile in excellent yield (86% over two steps) without the need for isolation and purification of the intermediate aldehyde.

In summary, a methodology for the conversion of an aldehyde to a nitrile facilitated by an oxoammonium salt is described in this section. Using HMDS as a nitrogen source, aldehydes can be converted to nitriles under mild conditions in fair to excellent yield. Both the success and the rate of the reaction are contingent on the formation and subsequent oxidation of the intermediate *N*-trimethylsilyl imine. The reaction is scalable and the spent oxidant can be recovered. Alcohols can also be easily converted to nitriles using the conditions outlined here in a two-step, one-pot approach.

2.5 Enhancing the Reactivity of TEMPO-derived Oxoammonium Salts: A Simple Electronic Modification Increases the Rate of Alcohol Oxidations

Stable nitroxide radicals have drawn considerable interest among chemists for use as spin labels, antioxidants, mediators in polymerization reactions, and as catalysts in organic synthesis.⁶⁴ A number of stable isolatable nitroxide species have been identified to date,⁶⁵ the most well-known of which is 2,2,6,6-tetramethylpiperidine 1-oxyl, more commonly referred to as TEMPO. The stability of such radicals arises from the absence of an α -hydrogen on the carbon adjacent to the nitrogen possessing the oxygen radical; the presence of α -hydrogens leads to decomposition.^{65c, 66} Furthermore, the lone pair of electrons on the nitrogen allows for resonance stabilization, and in the case of TEMPO and its analogues, additional shielding of the radical is provided by the four adjacent methyl groups.

The steric bulk of TEMPO and its analogues, while beneficial to the radical stability, tends to limit the interactions between the radical and substrates in systems where it is employed as an oxidation catalyst. Dupeyre and Rassat⁶⁷ made the astute observation that a nitrogen atom located between two adjacent bridgehead carbons could possess an α -hydrogen, yet provide a suitable environment for an N-oxyl radical. This clever application of Bredt's rule, which prevents elimination of the α -hydrogen, hinders decomposition of such nitroxide derivatives (Figure 2-9), and has allowed for the use and further development of less encumbered nitroxide catalysts such as AZADO, ABNO, and their derivatives for

oxidation chemistry; Iwabuchi et. al. have extensively advanced these catalysts for use in various applications.⁶⁸ More recently, Szpilman and co-workers⁶⁹ have implemented a rigid core structure, which allows for the presence of an α -hydrogen in their isoindole and iso-azaphenylene derived nitroxides (Figure 2-9).

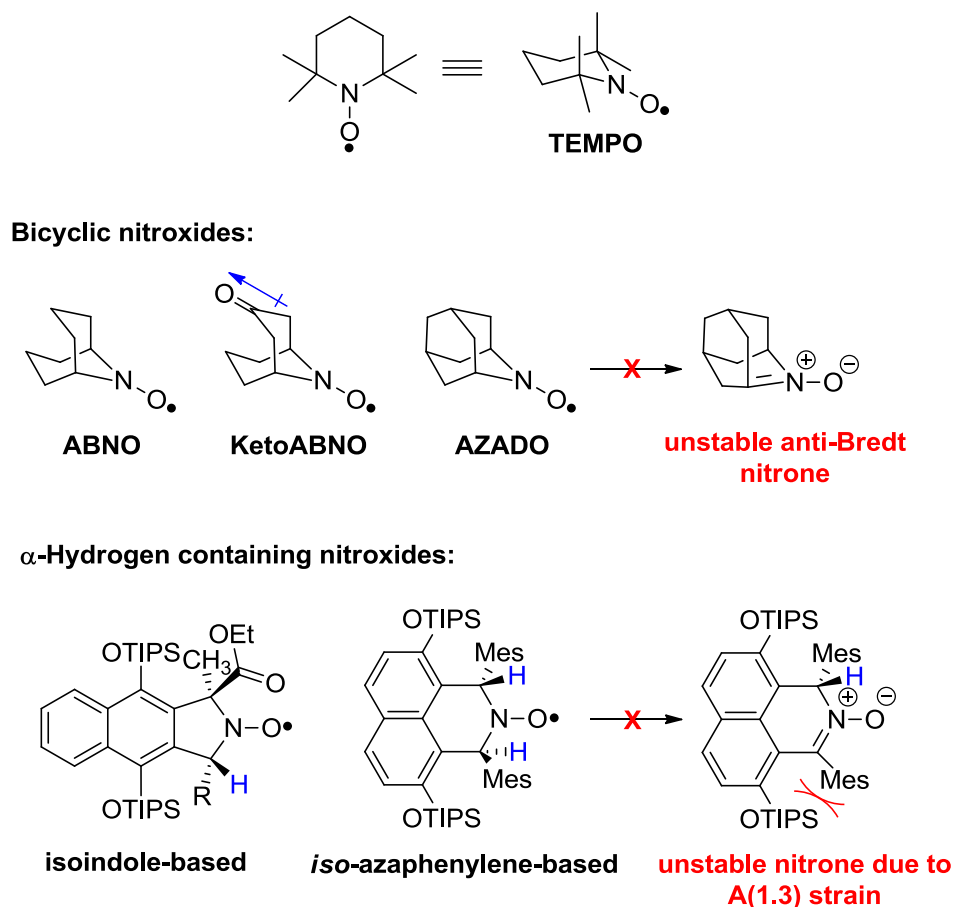


Figure 2-9

TEMPO and its derivatives, despite being encumbered, are among the most readily available, synthetically accessible, and prevalent nitroxides used in organic synthesis.⁶⁵ While the structural motif of nitroxide catalysts has been a primary focus of catalyst design, a less commonly addressed, but equally important factor to consider is the influence of substituents with varying electronic character on the nitroxide reactivity. Until recently, this aspect seems to have received little attention.

It has been reported that certain nitroxyl catalysts outperform one another under given experimental conditions, and this variation in reactivity is usually attributed to a difference in steric bulk

(i.e. AZADO vs. TEMPO).^{68a} However, it has been noted that in cases where the steric difference between two catalysts is negligible, the catalyst with an electron-withdrawing substituent or a structurally induced dipole that withdraws electron density is more active. Kanai and co-workers³³ reported that ketoABNO was more effective than ABNO in their copper catalyzed oxidation of secondary amines to imines; the authors highlighted that this result was a consequence of the electron-withdrawing ability of the carbonyl group. Similarly, in a computational study of 124 structurally and electronically different nitroxides conducted by Coote and co-workers,⁷⁰ they observed the general trend that electron-donating substituents tended to decrease the calculated oxidation potentials, whereas electron-withdrawing substituents increased the calculated oxidation potential. This result was confirmed by Szolcsányi and co-workers,⁷¹ where they synthesized and experimentally measured the redox potentials of a variety of mono and dinitroxyl amides. More recently, Minter, Sigman and co-workers⁷² have developed a methodology to computationally predict the electrochemical potential, catalyst activity, and deduce the structural-activity relationships that correlate well with experimental measurements.

These discoveries have been influential in leading to the development of new nitroxide-based catalysts, but there remain a few practical aspects to consider. Many of these innovative nitroxide catalysts are considerably more expensive than TEMPO or they are not commercially available and require several synthetic steps to yield small quantities of product. This severely limits the application of such novel nitroxides as general oxidation catalysts in organic synthesis. More notably, in applications where nitroxides are employed as oxidation catalysts, it is not the nitroxide species that facilitates the substrate oxidation, but rather the corresponding *N*-oxoammonium cation (Scheme 1-13); thus, the stability of this cation must be considered.^{73, 74} The *N*-oxoammonium cation can be generated through a one-electron oxidation of the nitroxide. In catalytic methodologies, this process is accomplished *in situ* by use of an inexpensive secondary chemical oxidant or electrochemically as described above in this work. In cases where use of a secondary oxidant complicates the synthesis due to undesired reactions with the substrate, it is advisable to prepare the *N*-oxoammonium salt separately for use as a stoichiometric oxidant, however this usually requires large (gram) quantities of oxidant.⁷⁵

While TEMPO is the most commonly used nitroxide catalyst, 2,2,6,6-tetramethylpiperidine, the precursor amine from which it is prepared is fairly expensive.⁷⁶ Several decades ago, it was realized that 4-amino-2,2,6,6-tetramethylpiperidine is structurally identical to the TEMPO precursor, yet it is significantly less expensive,⁷⁷ as it is easily prepared on an industrial scale through condensation of acetone and ammonia at high pressure as discussed earlier in this work (Scheme 1-3).⁷⁸

Masking the amine group present at the 4-position as an amide prevents any detrimental side reactions during the preparation of the bench-stable nitroxide, 4-acetamido-2,2,6,6-tetramethylpiperidine 1-oxyl (4-acetamidoTEMPO, **2**) which is afforded as an easy-to-handle, orange, crystalline solid.^{75, 79} The oxoammonium salt is easily obtained upon further oxidation, and it has been found that incorporating a tetrafluoroborate anion leads to a high-melting, bench-stable oxoammonium salt isolated as a yellow, crystalline solid.^{75, 80} This amide-containing oxoammonium salt features unique solubility properties, which as a practical matter, drastically simplifies the work-up of oxidation reactions, as careful choice of solvent allows for easy separation from oxidized substrates.⁷⁵ This slight modification of the TEMPO backbone, while realized simply for convenience, has arguably led to one of the most versatile oxidizing agents available, 4-acetamido-2,2,6,6-tetramethyl-1-oxopiperidinium tetrafluoroborate (**1**), commonly referred to as “Bobbitt’s salt” (Scheme 1-5). This oxoammonium salt and its prerequisite nitroxide, 4-acetamidoTEMPO (**2**), are commercially available from major chemical suppliers, but it is more economical to prepare these reagents in multi-molar quantities from the precursor amine using known procedures (Scheme 1-5).^{75, 79, 80}

Bobbitt’s salt (**1**) and nitroxide (**2**) have been employed as both stoichiometric and catalytic oxidants in a plethora of methodologies (Figure 2-10). In some cases, it has been reported⁸¹ that **2** was chosen as a preferred catalyst due to its highly selective nature as well as a greater stability in high pH solutions. Stahl and co-workers⁸¹ recently reported that **2** was a much more effective and stable electrocatalyst when compared to other nitroxide derivatives outperforming its less sterically hindered bicyclic counterparts especially in high pH solutions. Intrigued by this observation as well as the general

trend that electron-withdrawing substituents increase the redox potential, it was of interest to develop a more reactive, yet relatively stable oxoammonium salt.

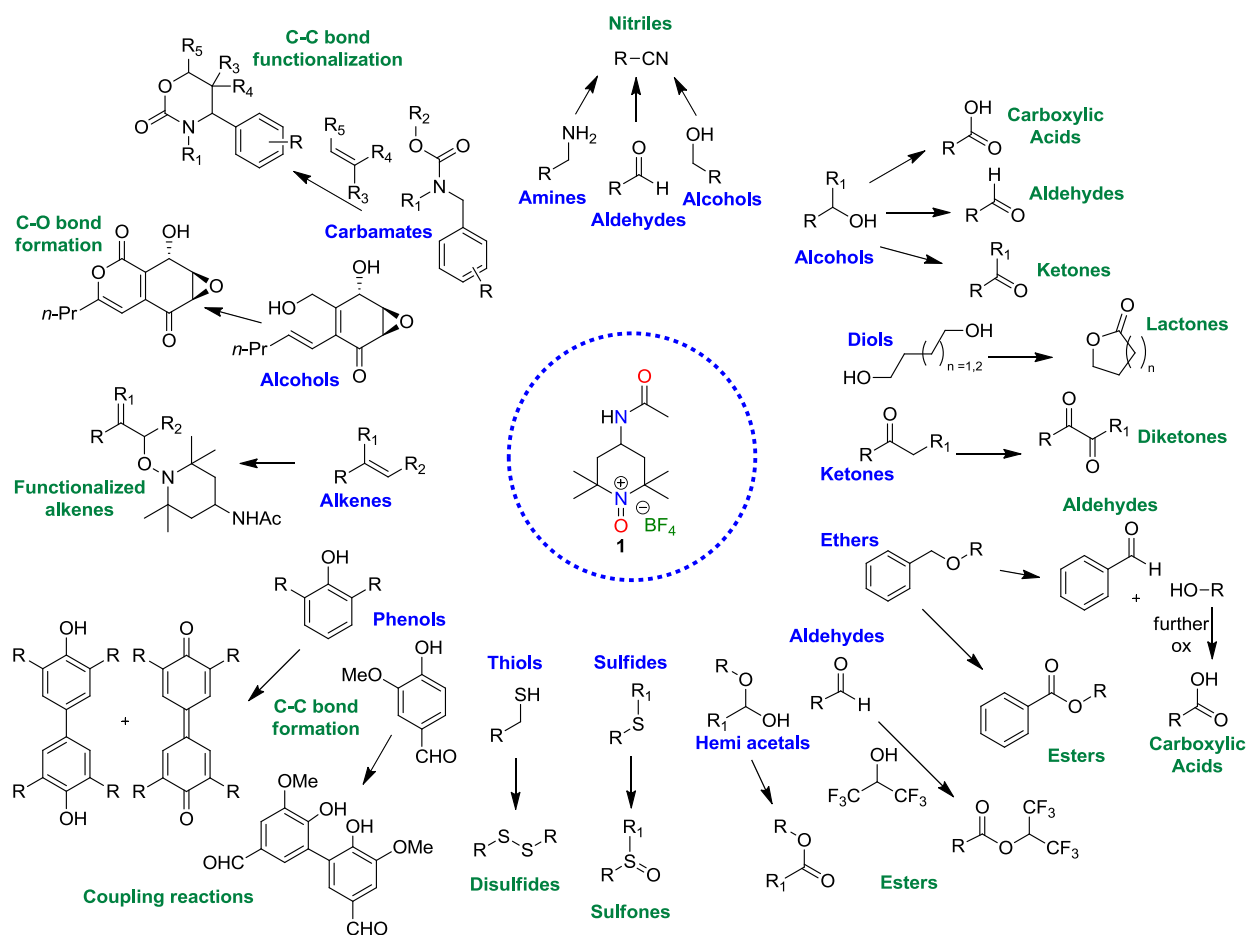
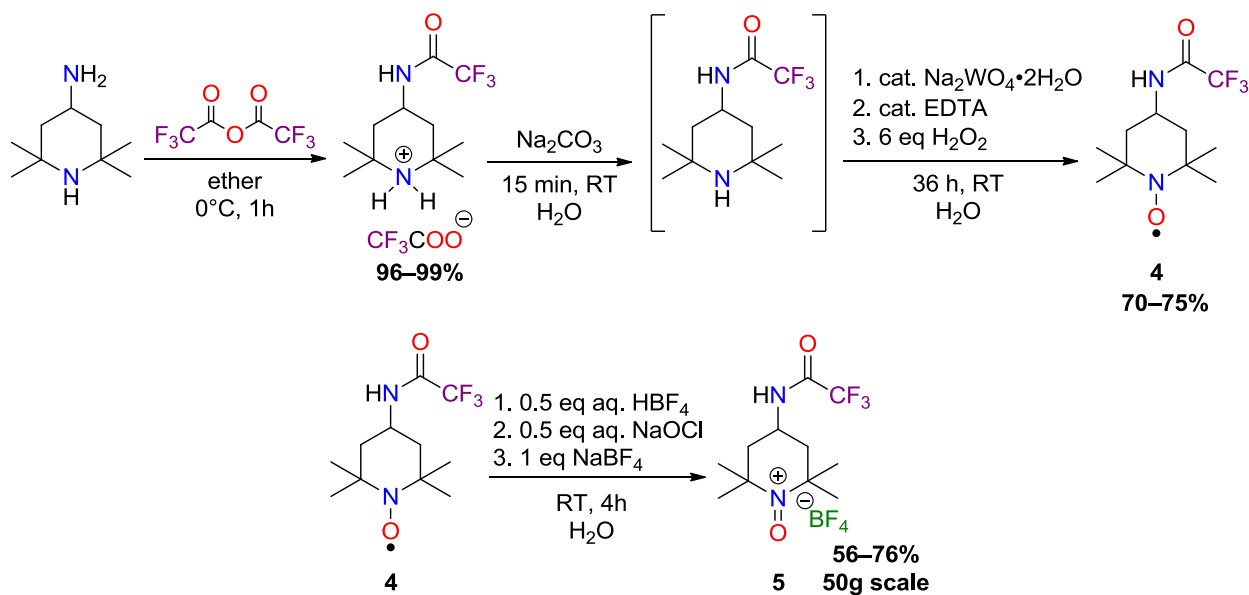


Figure 2-10^{65b}

A TEMPO-based nitroxide containing a trifluoromethylacetamide group (**4**) subjected to a cyclic voltammetry study by Szolcsányi and co-workers⁷¹ became of interest as it exhibited a large difference in anodic and cathodic peak potentials ($\Delta E = 130\text{mV}$), almost double that of the 4-acetamido derivative (**2**) ($\Delta E = 70\text{mV}$). Additionally, **4** exhibited an anodic/cathodic peak current ratio of 1.5, which suggested reversibility of the nitroxide/oxoammonium cation system. The placement of the trifluoromethyl group on the amide modifies the electronic character of the 4-acetamido derivative (**2**), and from a synthetic aspect, could be easily prepared with the slight modification of a well-established and economical procedure.⁷⁵ As outlined in Scheme 2-21, 4-trifluoromethylacetamidoTEMPO (**4**) is prepared in multi-

gram quantity from 4-amino-2,2,6,6-tetramethylpiperidine and trifluoroacetic anhydride. The isolated yields of the acetylation are indifferent between the two derivatives (**2** & **4**); however, the oxygenation of the hindered nitrogen with hydrogen peroxide and a tungsten catalyst differs significantly in time and slightly in yield. This is a testament to the difference in both electronic and physical properties of the two derivatives. Both derivatives undergo facile oxidation to their respective oxoammonium salts, however, 4-trifluoromethylacetamido-2,2,6,6-tetramethyl-1-oxopiperidinium tetrafluoroborate (**5**) is isolated in a lower yield as compared to Bobbitt's salt (**1**).



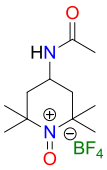
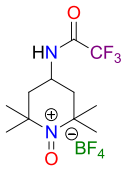
Scheme 2-21

Oxoammonium salt **5** is isolated as a high-melting yellow-crystalline solid, (mp $160\text{--}162^\circ\text{C}$, dec.), but its difference in reactivity as compared to **1** was quickly realized. When left open to the air on the lab bench over the course of a few days the sample turned white in color. The material was identified as 1-hydroxy-2,2,6,6-tetramethyl-4-(2,2,2-trifluoroacetamido)piperidin-1-ium tetrafluoroborate, the reduced form of oxoammonium salt **5**. This perhaps occurs through oxidation of residual moisture, oxygen, or other contaminants in the atmosphere. This is a slow process, similar in result, to what Endo observed when the *N*-oxoammonium salt of TEMPO is heated in water.^{82, 83} However, **5** is surprisingly stable when left dissolved in an aqueous solution and sealed under argon over weeks, thus it is likely

residual moisture is not the source of decomposition. Furthermore, **5**, can be stored for a period of several months without degradation in a sealed plastic container under an argon or nitrogen atmosphere.

The solubility of the two different oxoammonium salts (**1** & **5**) was measured in ether, ethyl acetate, water, dichloromethane, and acetonitrile. The results are shown in Table 2-8.

Table 2-8

solvent ^a	solubility ^b in g/L (M)	solubility ^b in g/L (M)
	 1	 5
cyclohexane	insoluble	insoluble
toluene	0.10 (3.3x10 ⁻⁴)	0.10 (2.8x10 ⁻⁴)
diethyl ether	insoluble	insoluble
dichloromethane	0.50 (1.7x10 ⁻³)	0.75 (2.1x10 ⁻³)
ethyl acetate	insoluble	0.85 (2.4x10 ⁻³)
acetonitrile	36.0 (0.12)	61.7 (0.17)
Water	70.4 (0.23)	30.4 (0.086)

^a All organic solvents were dried prior to use by either distillation from a dark purple solution of Na/benzophenone or calcium hydride or MgSO₄. ^b Solubility is expressed as grams of solute per liter of solvent, and as moles of solute per liter of solvent within the parentheses.

A brief inspection of the data in Table 2-8 illustrates that the 4-trifluoromethylacetamido derivative **5** is more soluble than the parent 4-acetamido oxoammonium salt **1** in more polar organic solvents, whereas in water it is less soluble. Of note, ~ 62 g of **5** dissolves in one liter of acetonitrile, whereas only ~ 36 g of Bobbitt's salt (**1**) dissolves. Comparing the molar quantities of each salt dissolved, **5** is 1.4 times more soluble than **1** in acetonitrile. In water, the solubility reverses ~ 70 g of **1** dissolves in one liter of water, whereas only ~ 30 g of **5** dissolves. Again comparing the molar quantities of the two salts, Bobbitt's salt (**1**) is 2.7 times more soluble in water than the 4-trifluoromethylacetamido

salt (**5**). With the relative solubilities of the two oxoammonium salts in hand, it was of interest to evaluate the relative rate of oxidation of a variety of alcohol substrates by each of the two salts.

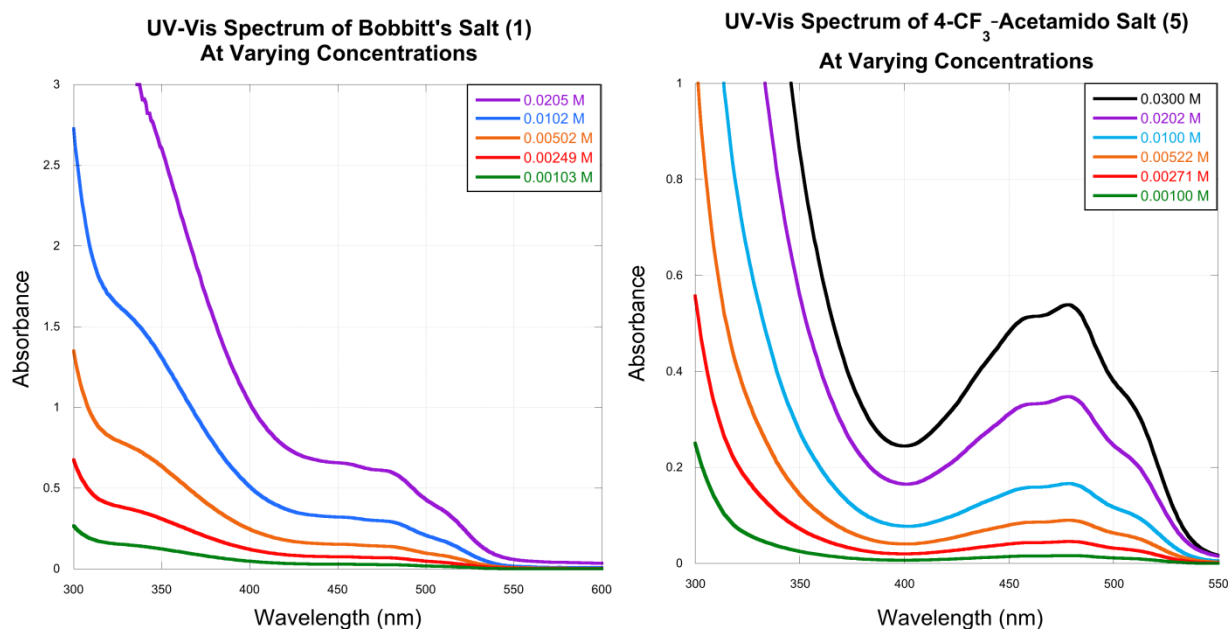


Figure 2-11

The unique colorimetric properties of oxoammonium salts allows for determination of the rate of disappearance of each oxoammonium salt by UV-Vis spectroscopy. Although oxoammonium salts **1** and **5** are yellow in color, each affords a unique UV-Vis spectrum. There is, however, substantial overlap (Figure 2-11). The overlap of the spectra is dealt with by employing the method of Blanco and co-workers,⁸⁴ which was further simplified by applying a least-squares analysis of the spectra using EXCEL Solver as described by Harris.⁸⁵

The individual concentration of each salt was approximately 0.005 M in the desired solvent, thus affording a total oxoammonium salt concentration of 0.01 M. At wavelengths greater than 370 nm this results in a total absorbance < 1.0 (Figure 2-11). The individual concentrations of each salt were monitored during alcohol oxidations at wavelengths between 370 nm and 530 nm; both **1** and **5** exhibit local absorption maxima in this range (**1**, 456 nm, 475 nm; **5**, 460 nm, 479 nm). Additionally, a large variety of alcohol substrates were available that did not absorb within this range. The hydroxylamine by-product of the oxidation also did not absorb in this range, ensuring minimal interference.

Standard solutions of each oxoammonium salt were prepared in dry acetonitrile solvent and the UV-Vis spectra were recorded individually (0.00500 M for Bobbitt's salt (**1**) and 0.00502 M for the 4-trifluoromethylacetamido derivative (**5**)). The molar absorptivity of each salt was calculated from the measured absorbance of these standard solutions⁸⁶ at 10 nm intervals from 370–530 nm as described by Harris.⁸⁵ This allowed for the calculation of an expected absorbance value for the mixture of two oxoammonium salts. By squaring the difference between the expected absorbance and the experimentally measured absorbance at 17 individual wavelengths,⁸⁷ and employing the “Solver” function in EXCEL, the concentrations of each oxoammonium salt are iteratively solved to provide the minimum for the sum of the differences.

The oxidation of alcohols by oxoammonium salt oxidants is second-order in nature; that is the rate of oxidation is dependent on both the concentration of the oxoammonium salt and the alcohol substrate. Experimentally, in an effort to simplify the kinetic analysis of the oxidation, a 100-fold excess of alcohol substrate was used relative to the oxoammonium salt, therefore the concentration of the alcohol substrate is considered constant. As a result, the oxidation can be treated as a pseudo-first order reaction, and by plotting $\ln [\text{salt}]$ vs. time (s), one obtains a linear fit with the slope = $-\text{rate of oxidation (s}^{-1}\text{)}$.

A typical UV-Vis experiment was as follows: to a dry 100-mL volumetric flask was added 147.2 mg of Bobbitt's salt (**1**), 168.3 mg of the 4-trifluoromethylacetamido derivative (**5**), and 100 mL of dry acetonitrile solvent. The mixture was sonicated for 2-3 minutes to ensure the oxoammonium salts were completely dissolved affording the stock solution of oxoammonium salts **1** and **5** to be used for the rate studies. The UV-Vis spectrum was taken of this stock solution to measure an initial absorbance reading. The alcohol substrate (0.50 mmol) was added to a clean, dry 3.5 mL x 10 mm x 10 mm quartz cuvette, the cuvette was placed in the UV-Vis spectrophotometer,^{88, 89} and an accurately measured 2.50 mL of the stock solution was quickly added to the cuvette. The UV-Vis spectrum was recorded for a given period of time (5.76 s – 300 s) depending on the substrate and rate of oxidation.⁹⁰ The first UV-Vis spectrum recorded was treated as the initial reading ($t = 0$ s). Any inconsistencies between the initial absorbance readings of the oxidation and those of the stock solution were accounted for by subtracting the two, and

then subtracting this difference from all absorbance readings measured to afford a “corrected absorbance reading” at each time (t). This corrected reading was used in the least squares analysis as described by Harris.⁸⁵ The plots of $\ln ([I])$ vs. time (s) and $\ln ([5])$ vs. time (s) for all substrates investigated can be found in the Experimental Section; a representative example of this plot, as well as the UV-Vis analysis, is shown below for the oxidation of *p*-methoxybenzyl alcohol (Figure 2-12). The rate of oxidation was determined from the slope of the linear least squares fit of these data.

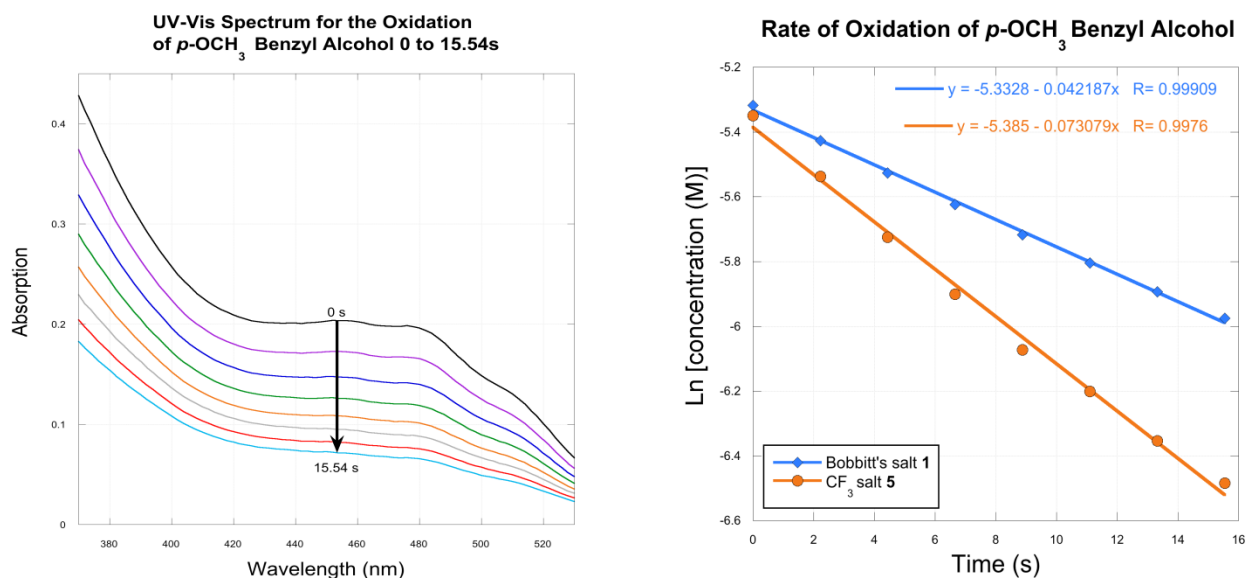
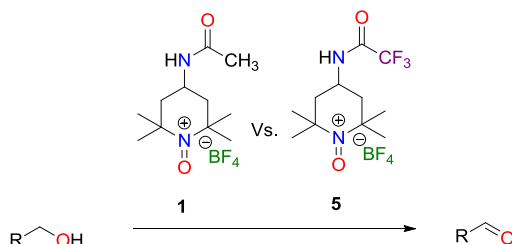


Figure 2-12

The individual rates of oxidation by **1** and **5** for each alcohol substrate, respective half-times, and the relative rates **5** / **1** are listed in Tables 2-9 and 2-10. In all cases, **5** was found to oxidize the alcohol substrate at a rate generally 1.2 – 3.2 times faster than **1**. Table 2-9 summarizes the data for various aliphatic, unsaturated, and activated alcohols. What can be concluded from the data is that secondary alcohols are oxidized faster than primary alcohols,^{91, 37a} and aliphatic alcohols are oxidized about 1.7 – 2.5 times faster by **5** than **1**. For example, the oxidation of 1-heptanol has a half-time of 66.8 minutes when oxidized by **1** and 31.1 minutes when oxidized by **5**; whereas, the oxidation of 2-hexanol has a half-time of only 12.6 minutes when oxidized by **1**, and 6.9 minutes when oxidized by **5**. However, when the alcohol is α,β -unsaturated such as in the case of allyl alcohol, there is a substantial rate increase for the oxidation; the half-times for the oxidation are 4.1 minutes when oxidized by **1**, and 2.0 minutes when

oxidized by **5**. This offers further evidence that the oxidation proceeds through a hydride transfer from the substrate to the oxoammonium cation, as substrates that offer inductive or resonance stabilization of a positive transition state are oxidized at a faster rate.

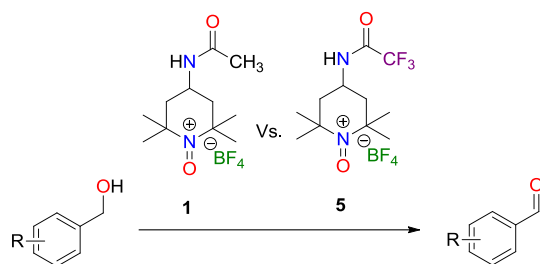
Table 2-9



Alcohol	Rate of Oxidation by Bobbitt's Salt 1 (s ⁻¹)	Half-time of Oxidation by Bobbitt's Salt 1	Rate of Oxidation by CF ₃ Salt 5 (s ⁻¹)	Half-time of Oxidation by CF ₃ Salt 5	Relative Rate of Oxidation (5/1)
1-heptanol	0.000173	66.8 min	0.000371	31.1 min	2.2
2-hexanol	0.000914	12.6 min	0.00167	6.9 min	1.8
neopentyl alcohol	0.0000385	5.0 h	0.0000965	2.0 h	2.5
cyclohexanol	0.00189	6.1 min	0.00333	3.5 min	1.8
cyclopentanol	0.00191	6.1 min	0.00333	3.5 min	1.7
allyl alcohol	0.00282	4.1 min	0.00580	2.0 min	2.1
cinnamyl alcohol	0.0145	47.8 s	0.267	2.6 s	18.4
piperonyl alcohol	0.0365	19.0 s	0.0980	7.1 s	2.7

There also appears to be a steric component that influences the rate of oxidation of aliphatic alcohols as well. This is not surprising given the four methyl groups located on both oxoammonium salts. Cyclohexanol and cyclopentanol, which are conformationally more rigid than 2-hexanol, oxidize at a slightly faster rate with half-times of ~ 6.1 minutes when **1** is employed and ~ 3.5 minutes when **5** is used as the oxidant. Neopentyl alcohol, a substantially more hindered substrate, is oxidized 5 times slower than 1-heptanol by **1** and 4 times slower than 1-heptanol by **5** (half-times: 5 h with **1**, 2 h with **5**; Table 2-9).

Table 2-10



R	Rate of Oxidation by Bobbitt's Salt 1 (s ⁻¹)	Half-time of Oxidation by Bobbitt's Salt 1	Rate of Oxidation by CF ₃ Salt 5 (s ⁻¹)	Half-time of Oxidation by CF ₃ Salt 5	Relative Rate of Oxidation (5/1)
<i>p</i> -OCH ₃	0.0422	16.4 s	0.0731	9.5 s	1.7
<i>p</i> -(<i>t</i> -Bu)	0.0165	42.0 s	0.0332	20.9 s	2.0
<i>p</i> -CH ₃	0.0208	33.3 s	0.0389	17.8 s	1.9
H	0.00751	1.5 min	0.00934	1.2 min	1.2
<i>p</i> -F	0.00325	3.6 min	0.00466	2.5 min	1.4
<i>p</i> -Br	0.00117	9.9 min	0.00371	3.1 min	3.2
<i>p</i> -CF ₃	0.000242	47.7 min	0.000531	21.8 min	2.2
<i>m</i> -OCH ₃	0.00283	4.1 min	0.00800	1.4 min	2.8
<i>m</i> -CH ₃	0.0101	1.1 min	0.0224	30.9 s	2.2
<i>m</i> -F	0.000932	12.4 min	0.00154	7.5 min	1.7
<i>m</i> -Cl	0.000653	17.7 min	0.00108	10.7 min	1.7
<i>m</i> -CF ₃	0.000365	31.7 min	0.000778	14.8 min	2.1

Piperonyl alcohol, with the hydroxyl group located in an activated benzylic position, is oxidized much faster: the half-time is 19 seconds when **1** is employed and only 7 seconds when oxidized by **5**. Cinnamyl alcohol is an anomaly, as it is oxidized 18.4 times faster by **5** than **1**. The exact origin of this significant rate difference is currently unknown, but it is postulated that cinnamyl substrates are oxidized much faster than most as there is extended conjugation into the aryl system, thus the steric environment around the reaction center is diminished as the aryl ring is further removed. Additionally, there may be an interaction between the π -system and the oxoammonium salt, perhaps with the N-H of the amide found in both **1** and **5**, leading to a stabilization of the transition state that substantially increases the rate of

oxidation. These observations are on par with what has been observed in oxidations involving cinnamyl substrates.^{59, 57}

The oxidation of alcohol substrates by oxoammonium salts has been known to proceed through a two-electron oxidation of the alcohol substrate where a hydride is removed from the carbon containing the hydroxyl group.^{39, 92} The results illustrated in Table 2-9 show that rate of oxidation is largely substrate dependent, and the general rate of oxidation follows a trend in which, the substrates that best stabilize a developing positive charge, as would be the case upon hydride removal, oxidize at a faster rate than substrates that do not.

In order to probe the influence of resonance and inductive effects on the rate of oxidation, a dozen *para* and *meta* substituted benzyl alcohols were oxidized with oxoammonium salts **1** and **5**, and the rates were compared. The data from these oxidations are summarized in Table 2-10. The most rapidly oxidized substituted benzyl alcohol was *p*-methoxybenzyl alcohol, while the slowest was *p*-trifluoromethylbenzyl alcohol (half-times: *p*-OCH₃: 16.4 s, **1**; 9.5 s, **5**; *p*-CF₃: 47.7 min, **1**; 21.8 min, **5**). In fact, if one compares the rate of oxidation to the Hammett parameters⁹³ that govern the acidities of substituted benzoic acids⁹⁴, a strong linear correlation is observed (Figure 2-13: $r = 0.9968$, **1**; $r = 0.9934$, **5**). From the Hammett plot, a ρ -value of -2.8 is extracted for the oxidation of substituted benzyl alcohols by **1**, and similarly, $\rho = -2.7$ when **5** is used as the oxidant. A negative ρ -value of this magnitude indicates the development of a substantial positive charge during the rate-limiting step of the oxidation.

The measured ρ -values of -2.8 and -2.7 indicates that oxoammonium salt oxidations are slightly more sensitive to the stabilizing/destabilizing effects of substituents than the oxidation of benzyl alcohols by Chloramine B.⁹⁵ The former oxidation exhibits a ρ -value of -2.14 and is proposed to also proceed through a hydride removal step, thus forming a positively charged transition state. The Hammett data strongly suggests that the prevailing mechanism^{39, 92} for the oxidation of alcohol substrates by oxoammonium salts is indeed correct; that is, the oxidation proceeds via removal of a hydride from the

substrate by the oxoammonium cation resulting in the development of a positively charged transition state. Substrates that are able to stabilize the transition state oxidize at a faster rate than ones that do not.

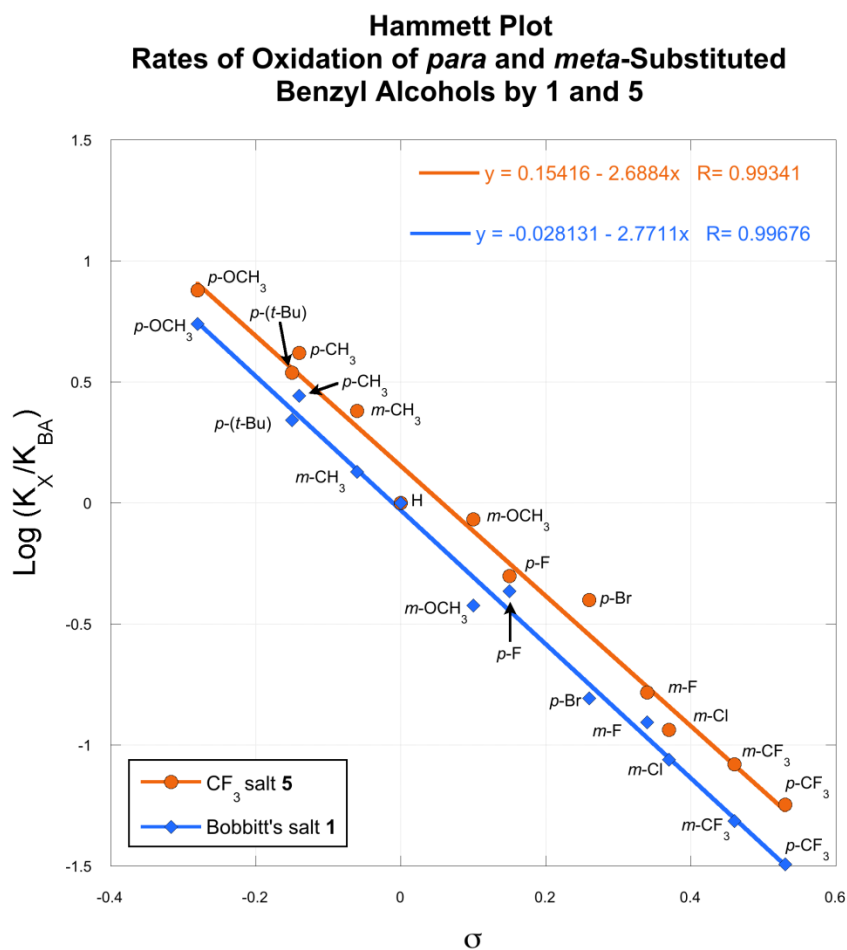
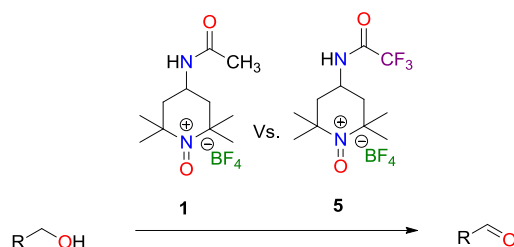


Figure 2-13

To ensure that the relative rate differences were not simply a result of solubility differences between **1** and **5** (Table 2-8), but rather, a consequence of the electronic modification of the oxoammonium salt, a small sample of oxidations were conducted in water;⁹⁶ where **1** is twice as soluble as **5**. The same result was obtained; oxoammonium salt **5** oxidizes the substrates at a rate 1.7–2.1 times faster than Bobbitt's salt **1** (Table 2-11). The individual rates of oxidation, however, are slower in aqueous solution than when conducted in acetonitrile, which is simply a result of the substrates being only partially soluble in the aqueous medium.

Table 2-11



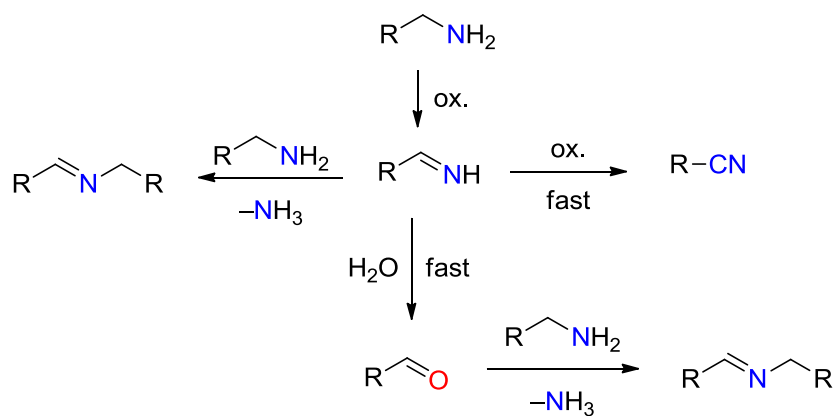
Alcohol	Rate of Oxidation by Bobbitt's Salt 1 (s ⁻¹)	Half-time of Oxidation by Bobbitt's Salt 1	Rate of Oxidation by CF ₃ Salt 5 (s ⁻¹)	Half-time of Oxidation by CF ₃ Salt 5	Relative Rate of Oxidation (5/1)
2-propanol	0.000244	47.3 min	0.000509	22.7 min	2.1
cyclohexanol	0.000880	13.1 min	0.00140	8.3 min	1.6
2-butanol	0.000321	36.0 min	0.000537	21.5 min	1.7

In summary, a slight electronic modification to the commercially available oxoammonium salt known as Bobbitt's salt **1** has been accomplished by replacing the 4-acetamido group with a 4-trifluoromethylacetamido group producing salt **5**. This electronic modification of the amide portion further withdraws electron density from the N=O⁺ portion of the molecule, thus increasing its oxidation-reduction potential, and as a result affords a more powerful oxidant. An efficient, practical procedure for the synthesis of **5** was developed on large scale and is presented in the Experimental Section. The rates of oxidation of a variety of alcohol substrates by each salt (**1** and **5**) were studied using UV-Vis spectroscopy. The relative rates of oxidation (**5/1**) were computed from the individual rates of oxidation, and **5** was found to oxidize alcohols at a rate 1.4–3.2 times faster than **1**. The oxidation of various substituted benzyl alcohols exhibited a strong linear correlation to the Hammett parameters that govern the acidities of benzoic acids. This offers credence to the fact that oxoammonium salt oxidations under neutral or slightly acidic conditions proceed via a hydride transfer process. The negative ρ -values of -2.8 and -2.7 reveal that both salts (**1** and **5**) are equally effected by nature of the substituents and are indicative of the development of a positively charged transition state, such as the case with hydride removal. In a broader perspective, the development of new nitroxides and their oxoammonium salt

counterparts should focus on the manipulation of the electron-withdrawing ability of substituents located on the oxidant. Modifications should be done without compromising the ease of synthesis, as the real virtue of reagents such as Bobbitt's salt, aside from exhibiting great versatility, is the ability to economically generate large quantities of oxidant.

2.6 Exploration into Imine Formation with Oxoammonium Salts and Related Chemistry

Oxoammonium salts have proven to be highly versatile oxidizing reagents and during the course of this work, a variety of useful oxidative transformations were discovered, but do not directly fit within the context the projects discussed above. The results of these explorations will be summarized in this section.

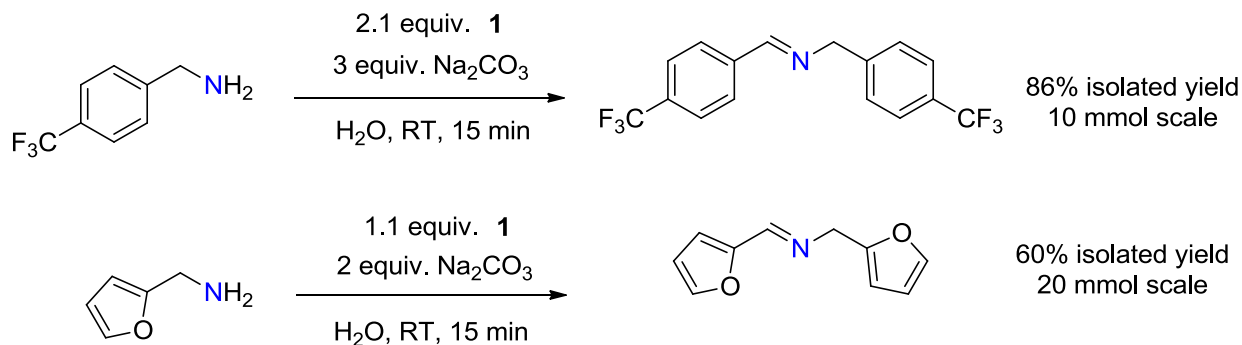


Scheme 2-22

While it has been reported that it is possible to access imines from the oxidation of primary amines through a variety of catalytic methods^{31–34}, stoichiometric transformations are more complex. The oxidation of the aldimine intermediate to furnish the nitrile product occurs rapidly and this process is favored to occur over imine formation as the nitrile product is computed to be more stable than the reactants by 14 kcal/mol (Scheme 2-22). The catalytic methodologies rely on specific ligands and coordination of the aldimine intermediate with the metal center to inhibit the second oxidative step, thus transamination can occur selectively affording the coupled imine product. When conducting the oxidation under stoichiometric conditions, it is possible to run the reaction fairly concentrated (greater than 0.5 M)

or use an excess of amine substrate in order to increase the yield of imine, but there is still an issue with selectivity as nitrile product is still produced. As described earlier in this work, the aldimine intermediate also rapidly reacts with water to afford aldehyde byproducts.

Overall, the development of such methods to furnish symmetrical homocoupled imines, in most cases, is futile as one of the most simplistic methods in organic chemistry can be employed to synthesize such imines via the condensation of an aldehyde with a primary amine followed by dehydration.⁹⁷ It is rather hard to justify a situation where the aforementioned procedure would not be the method of choice as aldehydes are readily available and primary amines are generally prepared from aldehydes through a reductive amination⁹⁸ in a process that inherently increases the cost of the amine substrate. Additionally, by employing different amine and aldehyde coupling partners selectivity in imine formation can be achieved and non-symmetrical imines are accessible. However, in cases when the need to adjoin two amine coupling partners arises, as can be necessary in complex molecule synthesis, an oxidative functionalization is possible using oxoammonium salt reagents.



Scheme 2-23

Two examples of selective oxidative cross-coupling to forge homocoupled imines from primary amines are illustrated in Scheme 2-23. In order to avoid the formation of nitrile products, the oxidation is conducted in aqueous solvent; once the first oxidation to the aldimine intermediate occurs, the aldimine undoubtedly is attacked by water and by loss of ammonia produces an aldehyde. The aldehyde then undergoes the prototypical condensation with another molecule of amine substrate producing the coupled imine product. This sort of oxidation requires that only half of the amine substrate be oxidized, thus

accounting for the comproportionation that occurs under basic conditions, 1.1 molar equivalents of **1** should be sufficient to accomplish this transformation. However, it was found that better isolated yields were obtained when an excess of **1** was employed. For example, when *p*-trifluoromethylbenzylamine was oxidized with 2.1 molar equivalents of **1** in an aqueous solution containing an excess of sodium carbonate an 86% isolated yield of the desired homocoupled imine was achieved. However, when furfurylamine was subjected to similar oxidation conditions, but employing only 1.1 molar equivalents of **1**, only 60% of the desired homocoupled product was isolated. While both are respectable yields and exhibit complete selectivity for the coupled imine product, a competing oxidation pathway was discovered during this work.

Irrespective of whether the imine formation occurs through amine attack on the aldimine or more likely aldehyde formations, then attack by another molecule of amine substrate, both processes release ammonia as a byproduct. What was discovered was that ammonia rapidly consumes oxoammonium salt oxidants, but the process by which this occurs is not fully understood. In a controlled experiment to deduce the mechanism of this process, Bobbitt's salt (**1**) was subjected to an atmosphere of anhydrous ammonia, and resulted in the formation of nitroxide (**2**). The experiment was conducted as follows: to a flame-dried two-neck round-bottomed flask was added a known quantity of Bobbitt's salt (**1**) and the flask was purged with dry argon gas. One neck served as a vent and was fitted to a mineral oil bubbler. The other neck, where the anhydrous ammonia gas would enter the flask, was attached with PTFE tubing to a drying tube containing solid calcium oxide. The other end of drying tube was attached with PTFE tubing through a stopper to a sealed Erlenmeyer flask which contained an aqueous solution of concentrated ammonium hydroxide. A hot plate was positioned under the flask and was used to warm the ammonium hydroxide solution evolving gaseous ammonia, which then passed through the calcium oxide in the drying tube, allowing for the removal of water. Anhydrous ammonia then gently flowed into the round-bottomed flask containing the oxoammonium salt (**1**). The set-up used is depicted in Figure 2-14.

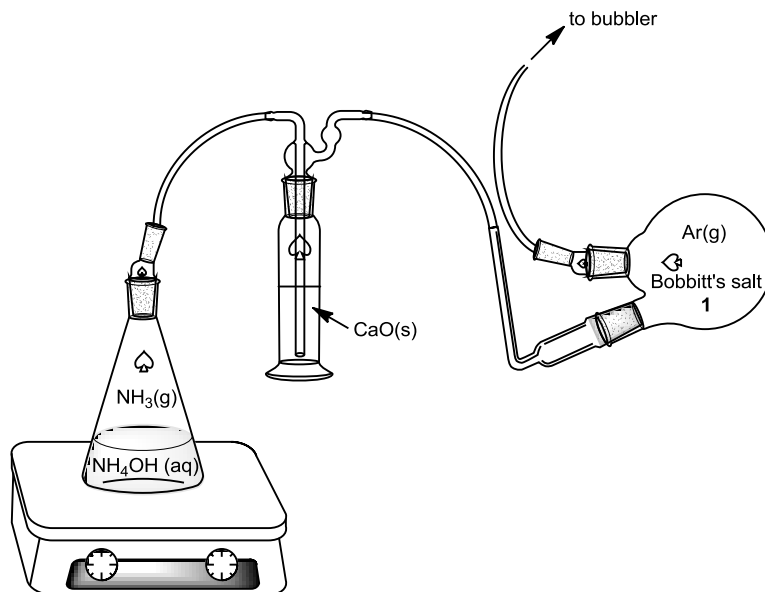


Figure 2-14

The instant anhydrous ammonia flowed into the flask containing the crystalline yellow solid **1**, a color change was observed to occur on the surface of the oxoammonium salt crystals from yellow to an off-white color, while concurrently the formation of an orange-red paste is observed, which eventually returns to a crystalline orange solid. During this process, the portion of the flask containing the oxoammonium salt rapidly warms, and the round-bottomed flask becomes warm enough to require a heat resistant glove to handle, indicating a very exothermic process was underway. Within a few minutes all of the oxoammonium salt was consumed and the flask cooled to room temperature. NOTE: In one instance when the gaseous ammonia was added rapidly, the flask became so warm that rapid decomposition of the oxoammonium salt and reaction products occurred emitting smoke within the flask and resulting in a black, charred solid. The product of this decomposition is unknown, and to avoid hazardous conditions associated with the exotherm, the reaction should be run on small scale < 1 mmol with slow addition of the gaseous ammonia. Closer inspection of the crude reaction mixture from the properly performed oxidation revealed that there was also a white solid mixed in with what was presumed to be the orange nitroxide crystals. The products of the reaction were easily established as the neat solids

could be analyzed using an attenuated total reflectance sampling technique in conjunction with Fourier transform infrared spectroscopy (ATR-FTIR), and compared with known reference samples.

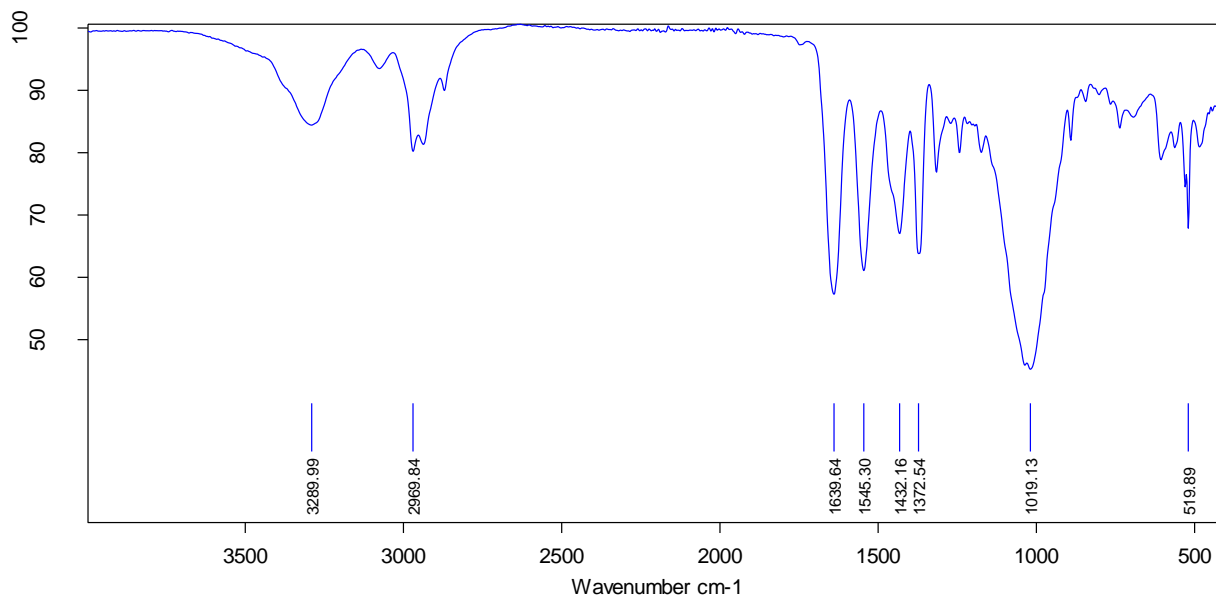


Figure 2-15

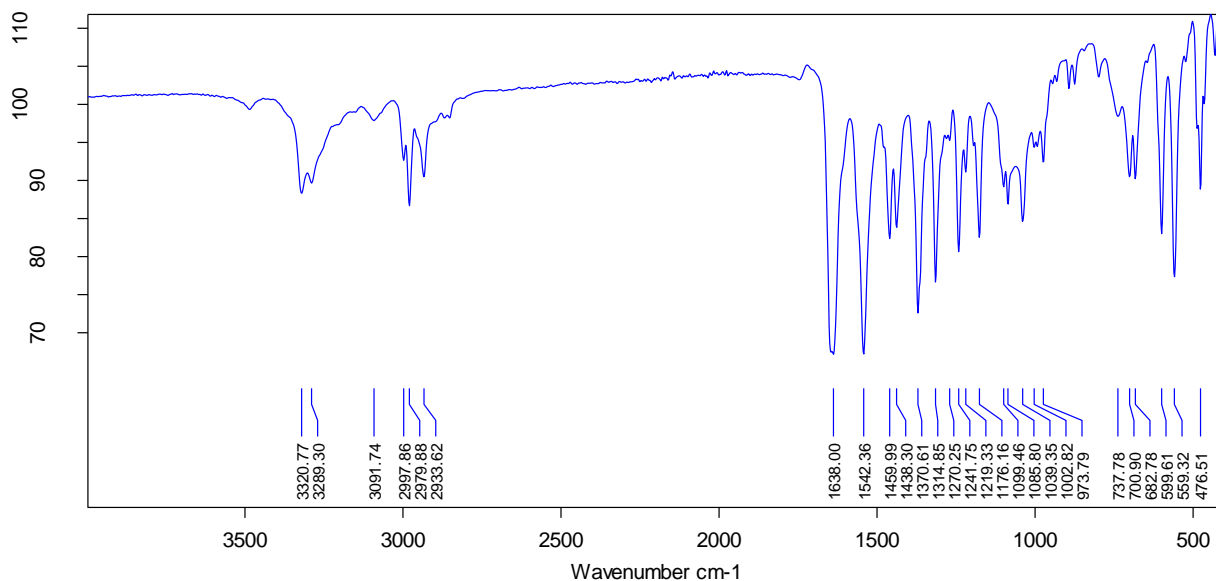


Figure 2-16

The ATR-FTIR spectrum of the crude reaction mixture is shown in Figure 2-15. The orange solid within the reaction mixture was established as the respective nitroxide (**2**) as it matched the following

peaks, reported in wavenumbers (cm^{-1}), found in the ATR-FTIR spectrum of the known reference standard of **2** (Figure 2-16): 3092 (v), 2970 (v), 2930 (v), 1640 (s), 1545 (s), 1430 (s), 1372 (v).

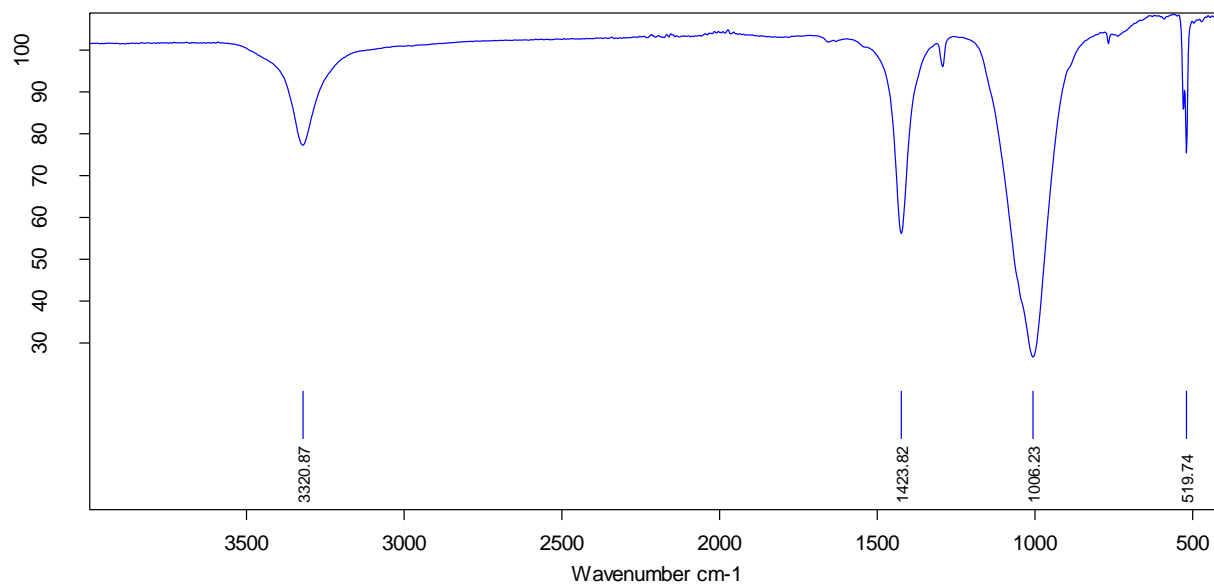


Figure 2-17

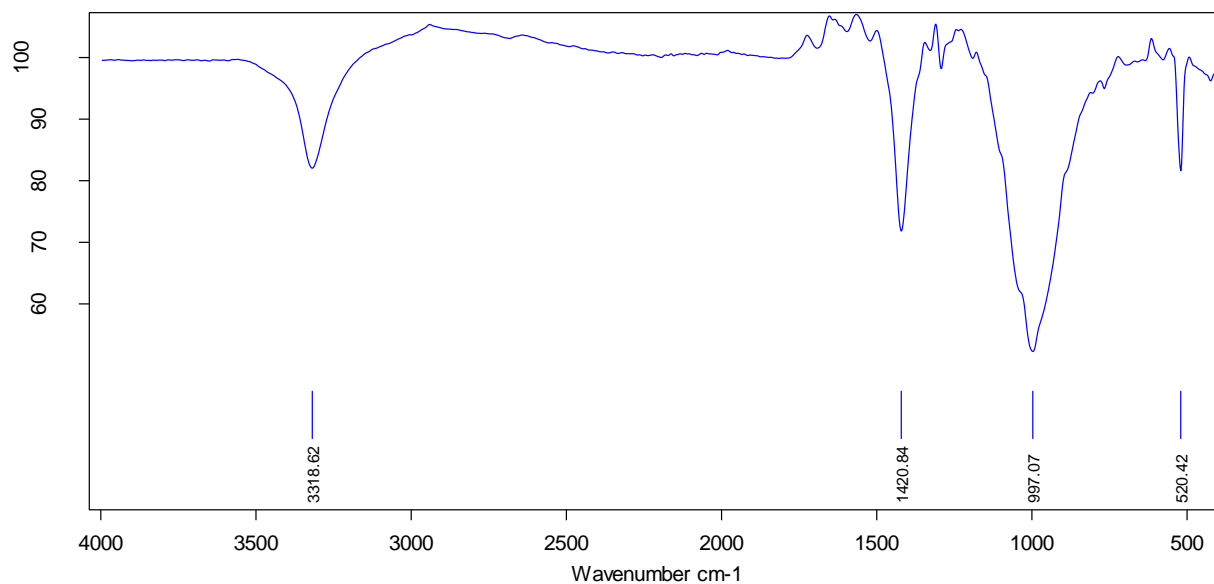


Figure 2-18

Dichloromethane was added to the crude reaction mixture solubilizing **2** and the resulting white solid that remained at the bottom of the flask was filtered and dried. This white solid produced an ATR-FTIR spectrum (Figure 2-17) that was an exact match with ammonium tetrafluoroborate; displaying the

following peaks in wavenumbers (cm^{-1}): 3320 (br, s), 1423 (s), 1006 (br, s), 520 (w), which are the only peaks found in the ATR-FTIR spectrum of ammonium tetrafluoroborate (Figure 2-18). No other products were observed in the crude reaction mixture.

Repeating the reaction, however, instead in dichloromethane solvent (~0.1 M) with bubbling of anhydrous ammonia into the slurry rather than neat, offered further insight to this oxidative process. The initial yellow slurry quickly turns light orange in color, a white precipitate forms, which was later identified as ammonium tetrafluoroborate, and after removal of the ammonia inlet the reaction mixture continues to vigorously bubble. While the reaction mixture did warm as the solvent serves as a “thermal sink”, it was only slightly above room temperature, thus the bubbling was not due to the refluxing of the solvent. This suggested that the product of the oxidation was likely a gas.

In the case that the reaction product was indeed a gas, it would have been purged off from the reaction flask through the vent. The neat reaction was then repeated, but using a thick-walled glass round-bottomed flask designed for high pressure applications. Cautiously, behind a blast shield, the reaction was repeated, but without a vent, and was stopped as soon as all of the yellow color of the solid oxoammonium salt had disappeared. The colorless headspace of the sealed flask, which was flushed with argon gas prior to the reaction, was then subjected to GC-MS analysis; however, the only gas detected was the argon. This observation led to the hypothesis that oxoammonium salts oxidize ammonia to nitrogen gas, which is challenging to detect as nitrogen constitutes ~ 78% of the Earth’s atmosphere by volume and special instrumentation would be necessary to detect its formation. In order for this oxidation to occur, two molecules of ammonia would have to add to one another in some fashion to forge a new N–N bond. One might propose it is more likely that ammonia, being a strong base, would add to the oxygen of the oxoammonium salt similar to what is observed with Grignard reagents.⁹⁹ However, such an intermediate would likely decompose into 4-acetamido-2,2,6,6-tetramethylpiperidine and nitric oxide, and the nitric oxide would quickly react with the oxygen in the atmosphere to form nitrogen dioxide resulting in a reddish-brown colored gas. This type of pathway is unlikely as neither the deoxygenated amine nor a

colored gas is observed during the reaction of oxoammonium salt **1** with ammonia. Additionally, this work has shown, as described above, that amines do not add to the oxygen of the oxoammonium salt.

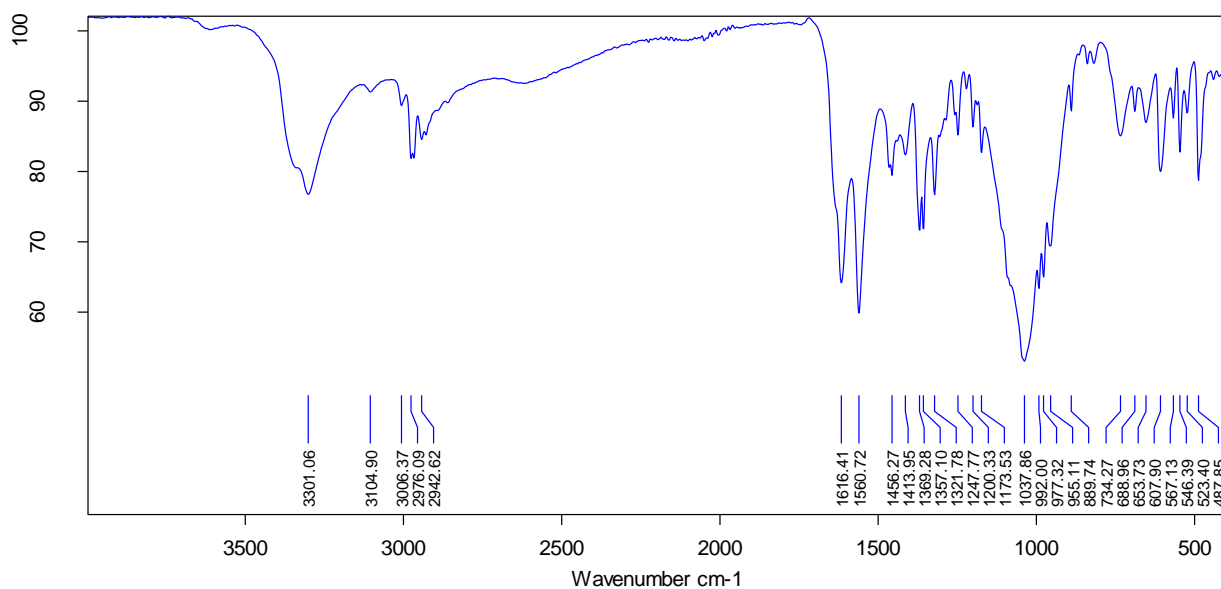


Figure 2-19

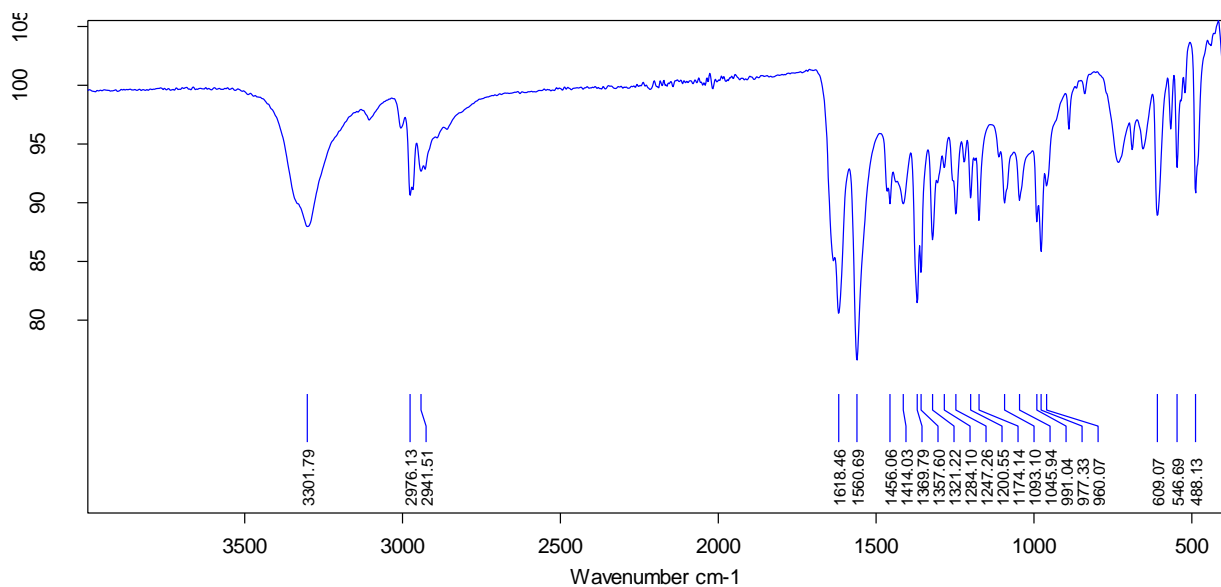


Figure 2-20

Returning to the proposal that oxoammonium salts could oxidize ammonia to nitrogen gas, a hydrazine-like intermediate would be required. In order to gather further information, an excess of hydrazine hydrate was added to a slurry of oxoammonium salt **1** in dichloromethane solvent. The light

yellow slurry initially became light orange, then eventually went colorless and a white precipitate could be observed at the bottom of the flask. After solvent removal and drying under reduced pressure, the crude white solid that resulted was analyzed by ATR-FTIR (Figure 2-19) and compared to known reference standards.

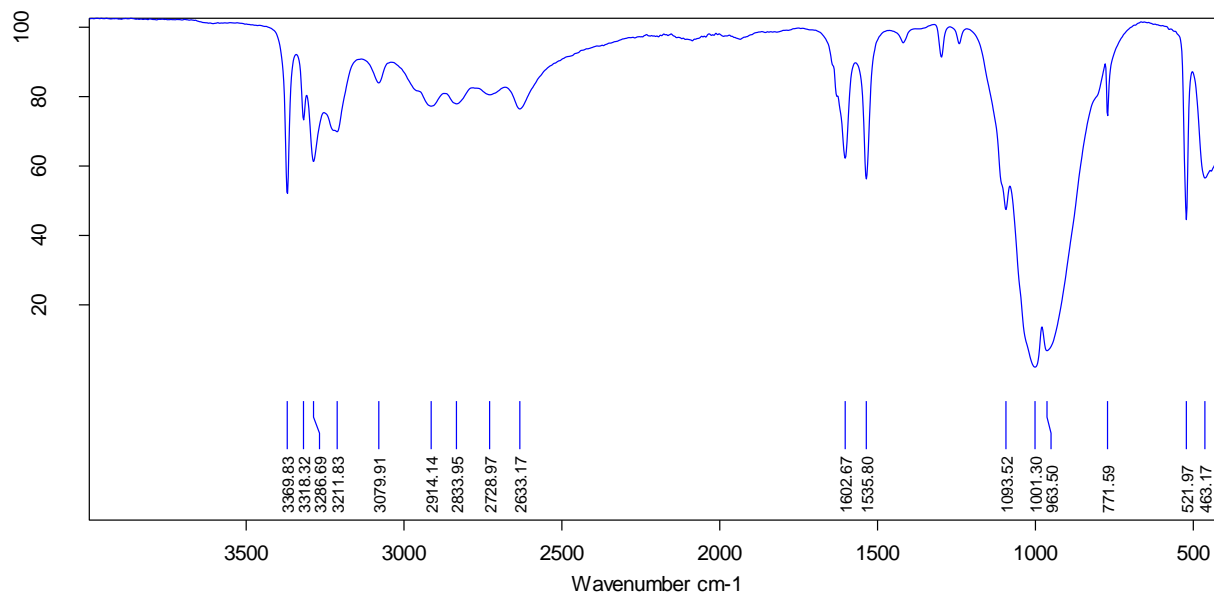


Figure 2-21

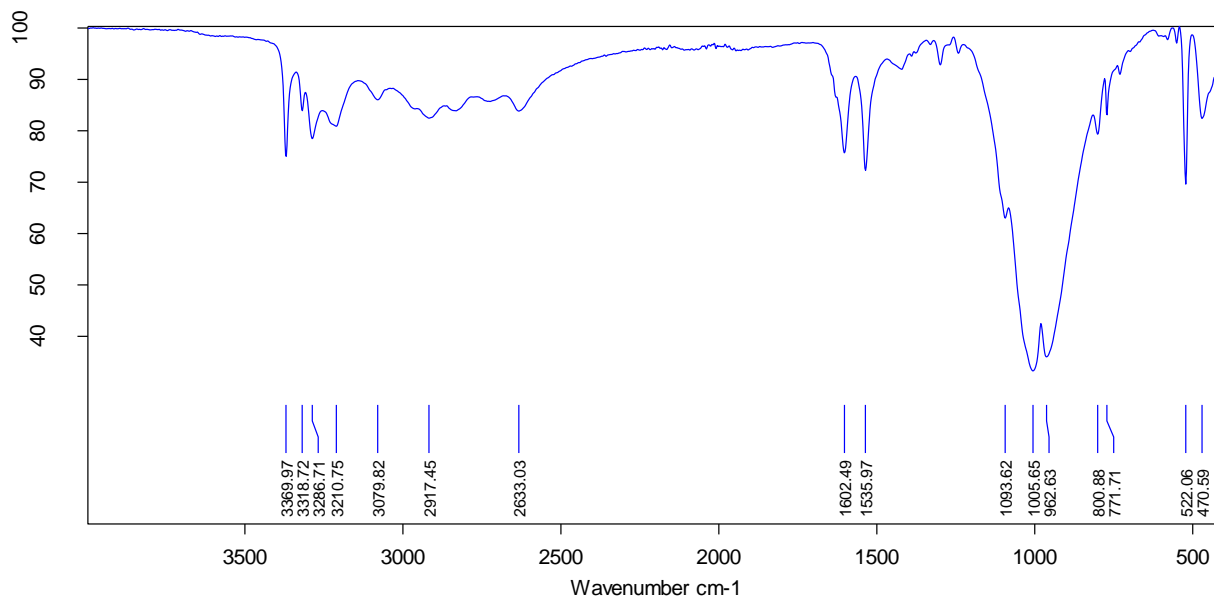


Figure 2-22

Free hydroxylamine **3** was identified in the crude reaction mixture from ATR-FTIR analysis, as the following peaks, reported in wavenumbers (cm^{-1}), were observed in the spectrum: 3301 (br, s), 2976 (w), 2942 (w), 1616 (s), 1560 (s) 1369 (m), 1321 (w), 977 (v), 734 (w), 608 (m), 546 (w), 488 (s), and matched the same peaks found within the reference ATR-FTIR spectrum of **3** (Figure 2-20).

The additional peaks within the spectrum were attributed the tetrafluoroborate salt of hydrazine as the following peaks, reported in wavenumbers (cm^{-1}), were closely related to peaks found in the ATR-FTIR of the product of the reaction of hydrazine monohydrate with tetrafluoroboric acid (Figure 2-21): 3360 (v), 2630 (br, w), 1602 (v), 1560 (v), 1037 (br, s), 523 (w). Indeed this was the case, as washing the crude reaction product with dichloromethane and taking the ATR-FTIR spectrum of the remaining white solid (Figure 2-22), an identical spectra is observed to that of the known reference standard of the tetrafluoroborate salt of hydrazine (Figure 2-21).

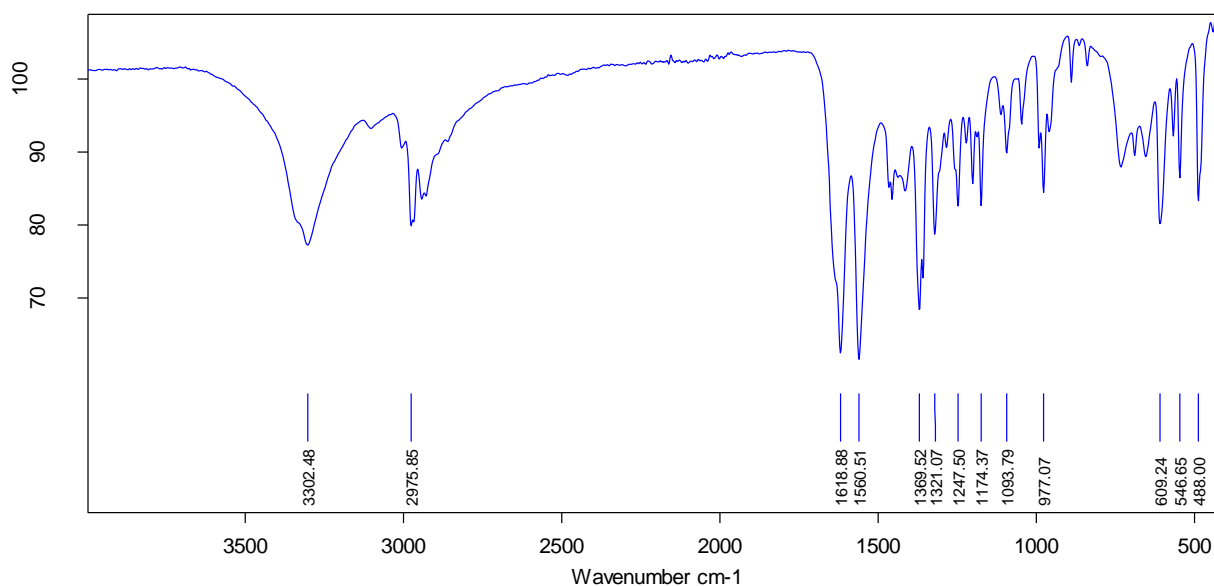


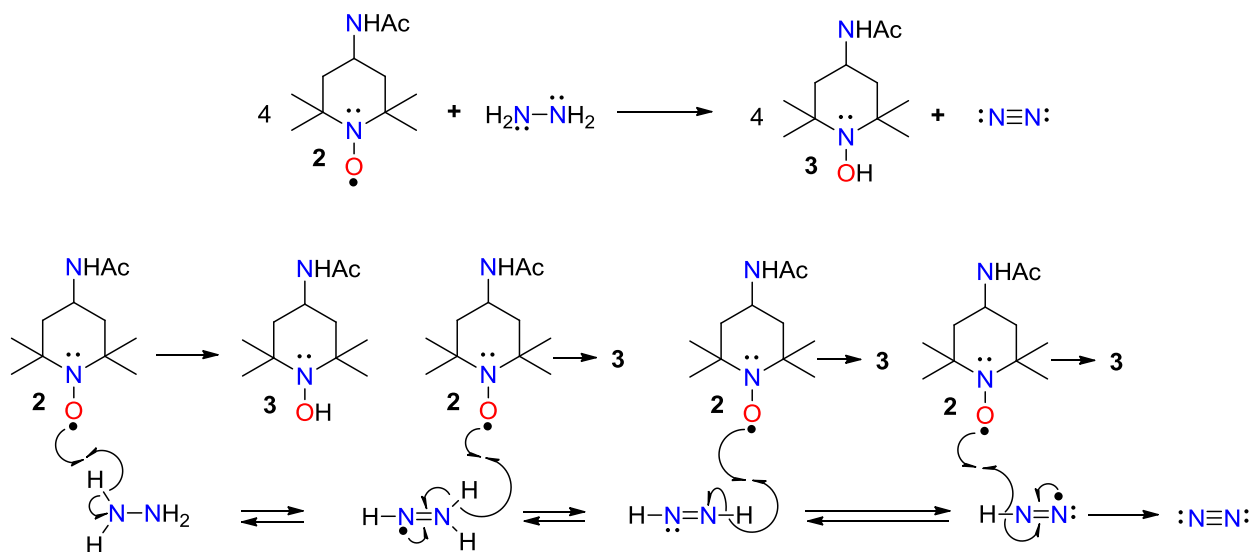
Figure 2-23

The formation of the free hydroxylamine is not surprising given the fact that phenylhydrazine is commonly employed to study nitroxide spin labels by NMR as it effectively reduces nitroxides to the free hydroxylamine.¹⁰⁰ Thus upon formation of the nitroxide, as a result of the oxidation, it is reduced to the hydroxylamine. This was confirmed independently as the crude product of the reaction of nitroxide **2** in

dichloromethane solvent with hydrazine monohydrate produced an identical ATR-FTIR spectrum (Figure 2-23) as the free hydroxylamine **3** (Figure 2-20). This reaction of **2** with hydrazine monohydrate in dichloromethane solvent proceeds at a slower rate than the reaction of **1** with hydrazine monohydrate in dichloromethane as the reaction mixture as evidenced by the rate of evolution of the gaseous product and the colorimetric changes associated with the processes.

The oxidation of hydrazine to produce nitrogen gas employing nitroxide **2** as the oxidant is likely the result of a radical process, as the nitroxide **2** is reduced to afford the hydroxylamine **3** through a one-electron reduction, but hydrazine requires 4 the loss of electrons to afford nitrogen gas. This would suggest that one molecule of hydrazine could potentially reduce 4 molecules of nitroxide (Scheme 2-24). The stoichiometry of which is certain, as 4 molar equivalents of nitroxide **2** in the presence of 1 molar equivalent of hydrazine hydrate goes to completion forming only the free hydroxylamine product, but 5 and 6 molar equivalents of nitroxide **2** in the presence of 1 molar equivalent of hydrazine hydrate does not go to completion and nitroxide **2** remains in the reaction mixture.

overall process:

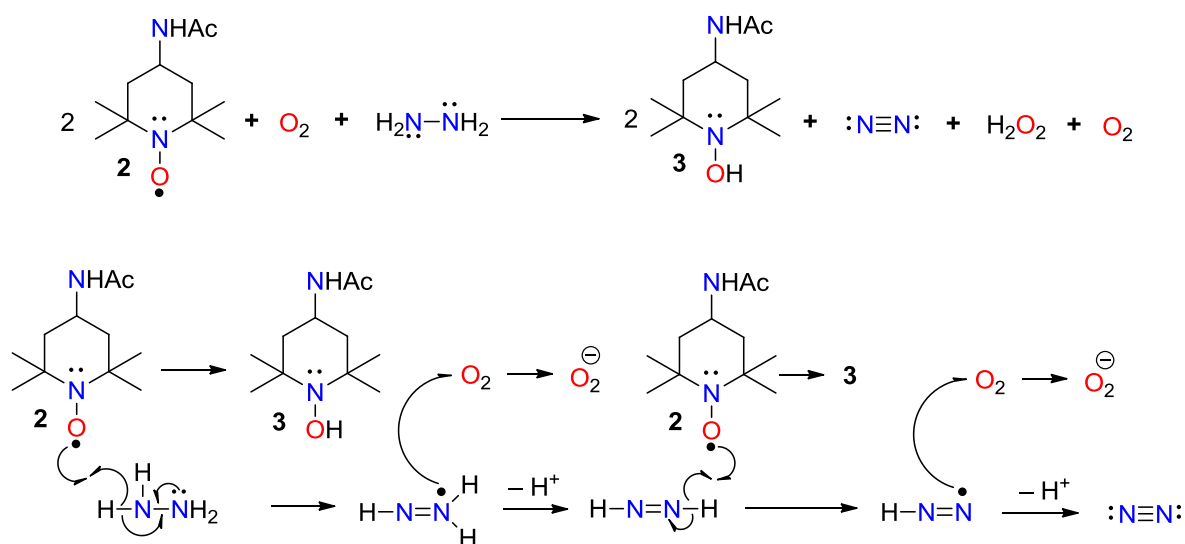


Scheme 2-24

Since the oxidation was conducted under open atmospheric conditions, the participation of molecular oxygen during the oxidation cannot be ruled out (Scheme 2-25).¹⁰¹ This type of process would

result in the reduction of two nitroxide molecules per molecule of hydrazine. The other two electrons would be scavenged by molecular oxygen forming two molecules of superoxide, which Misra and Fridovich¹⁰¹ proposed was a key intermediate in the oxidation of phenylhydrazine in aqueous, buffered solutions. The two superoxide intermediates eventually result in the production of hydrogen peroxide and molecular oxygen as byproducts of the oxidation; this has not been confirmed experimentally. The important conclusion to be drawn from these studies is that nitroxide **2** ultimately is reduced to the hydroxylamine **3** and that the oxidation of hydrazine with **1** as compared to **2** proceeds at a faster rate.

overall process:



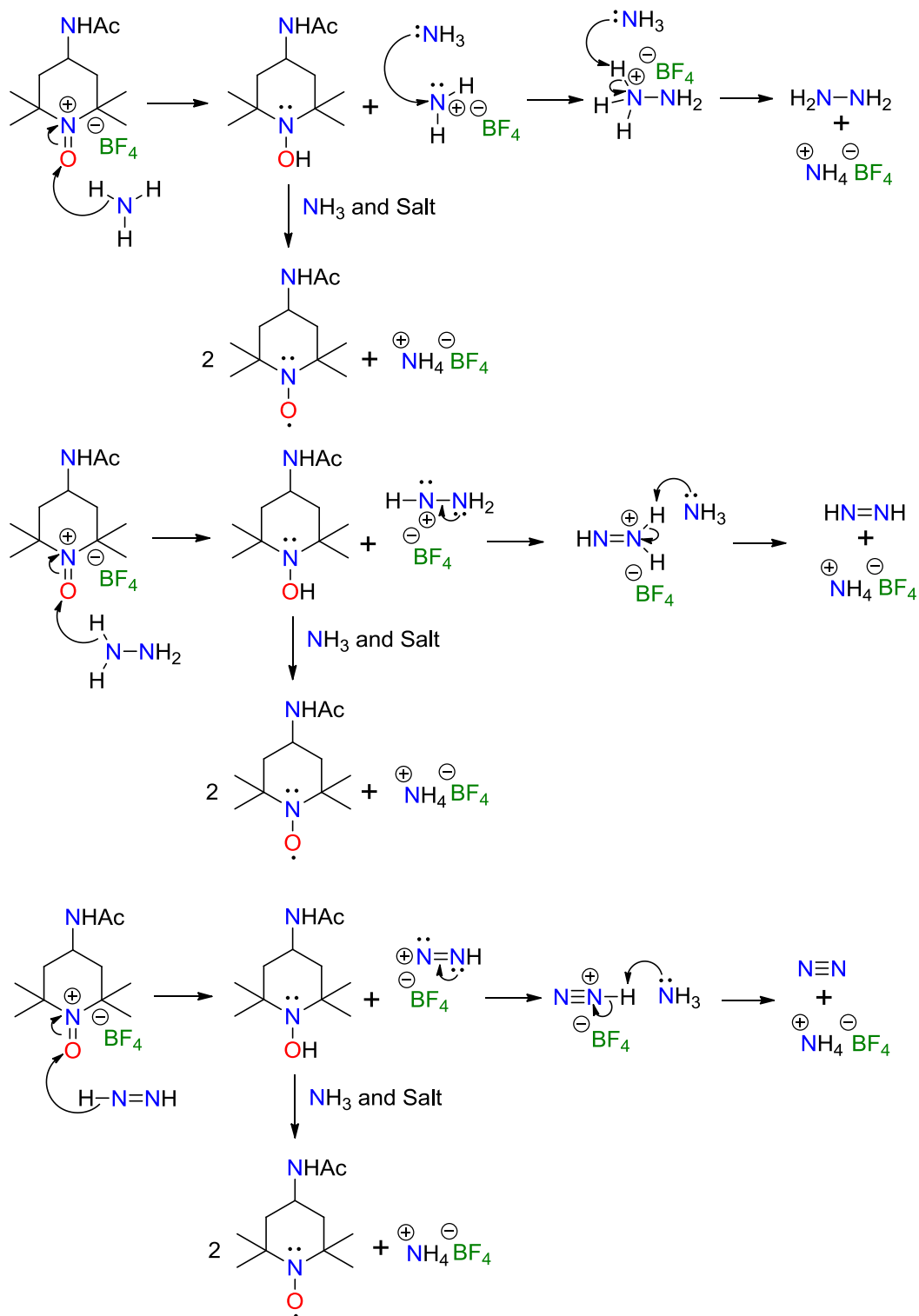
Scheme 2-25

The observations above suggest that if the oxidation of ammonia to nitrogen gas by **1**, produces hydrazine in the initial step, then the hydrazine product can be further oxidized by both salt **1** and nitroxide **2** through separate processes. It has been shown above that the oxidation of hydrazine by **2** affords the free hydroxylamine **3**, which, under the basic reaction conditions can then comproportionate with **1** to afford two molecules of **2**. The end result is the rapid consumption of the oxoammonium salt **1**. While all of the processes described above are at work to some extent during the oxidation, the primary pathway for the oxidation of ammonia to nitrogen gas likely involves the oxoammonium salt **1** versus nitroxide **2** as the end resultant of the oxoammonium salt **1** is identified as the nitroxide **2** (Figure 2-15).

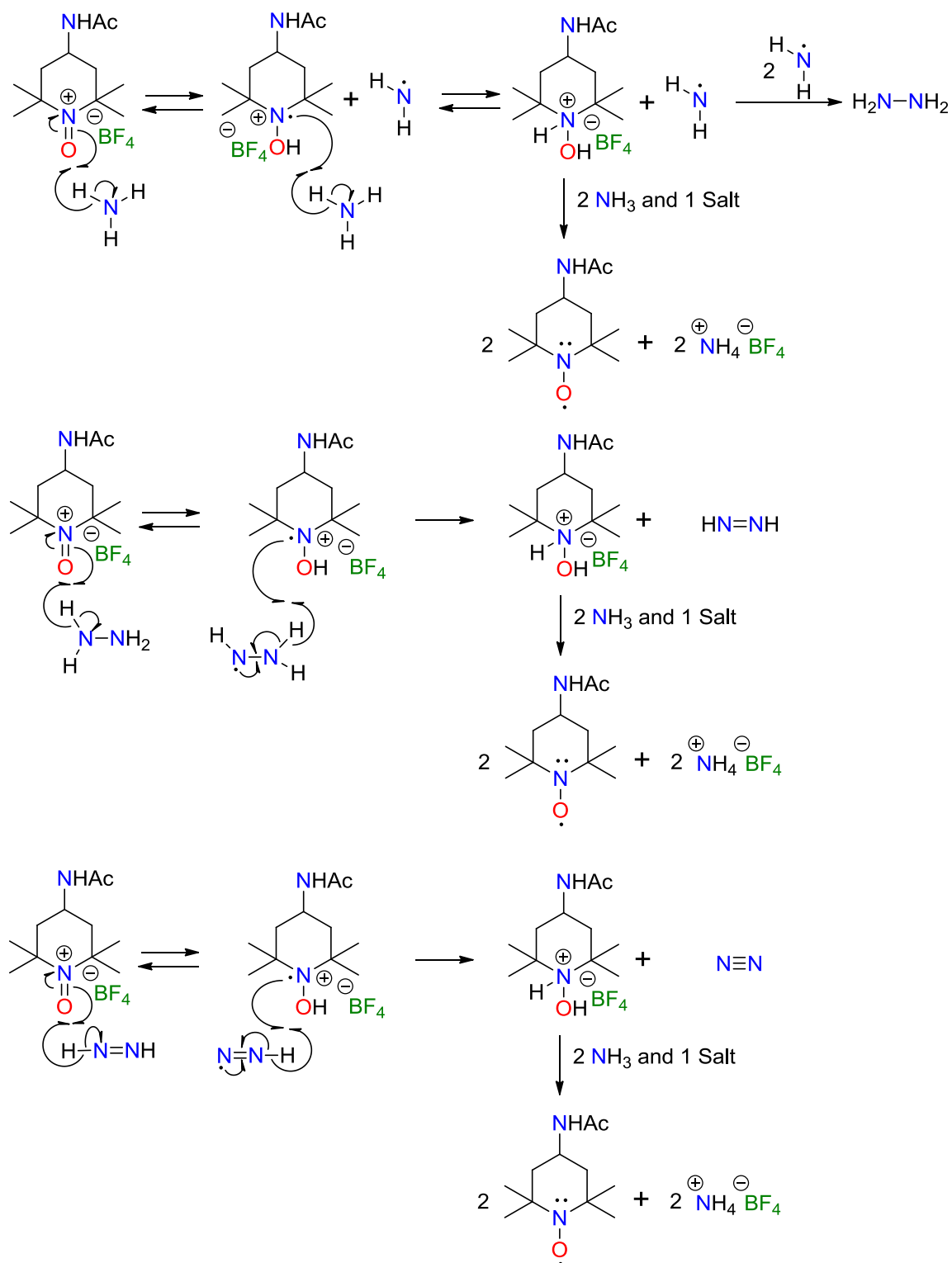
Thus, the oxidation of hydrazine to nitrogen gas by the nitroxide **2** is a slower process as little to no hydroxylamine **3** is produced during the oxidation.

There are two possible ways in which the oxidation of ammonia to nitrogen gas by oxoammonium salts can take place; a two-electron process through a hydride removal from ammonia (Scheme 2-26) or a one-electron process through hydrogen abstraction (Scheme 2-27). In the two-electron process, the first step in the oxidation must be that the oxoammonium salt removes a hydride from the ammonia resulting in **3** and what should be considered a very reactive NH_2^+ species. This reactive species could be attacked by another molecule of ammonia to forge the N–N bond of hydrazine. The comproportionation process of **3** with another molecule of **1** would afford two molecules of nitroxide **2** and ammonium tetrafluoroborate. The hydrazine product would be further oxidized as shown in Scheme 2-26 to afford nitrogen gas; an entropically favored product. The overall process would consume six molar equivalents of **1** to afford one molecule of N_2 , six molar equivalents of **2**, and six molar equivalents of ammonium tetrafluoroborate; these are the only products observed experimentally.

A second proposed mechanism, which is reminiscent of the Raschig and Olin-Raschig processes¹⁰² in that a radical coupling of two NH_2^\bullet radicals forges the N–N bond is illustrated in Scheme 2-27. In this proposed mechanism, the oxoammonium salt abstracts two hydrogen atoms from ammonia affording the protonated tetrafluoroborate salt of **3** and two NH_2^\bullet radicals. The NH_2^\bullet radicals would then couple to form the N–N bond of hydrazine and the protonated tetrafluoroborate salt of **3**, which would then comproportionate under the basic reaction conditions to afford **2** and ammonium tetrafluoroborate. The hydrazine product would undergo a hydrogen abstraction process with additional equivalents of **1** to afford nitrogen gas as outlined in Scheme 2-27. The overall process would consume six molar equivalents of **1** to afford one molecule of N_2 , six molar equivalents of **2**, and six molar equivalents of ammonium tetrafluoroborate resulting in the same products as obtained from the proposed two-electron oxidation process shown in Scheme 2-26. Thus, it can be concluded that NH_3 reacts rapidly with oxoammonium salt oxidants affording the nitroxide **2**, ammonium tetrafluoroborate, and the oxidized product, N_2 gas.

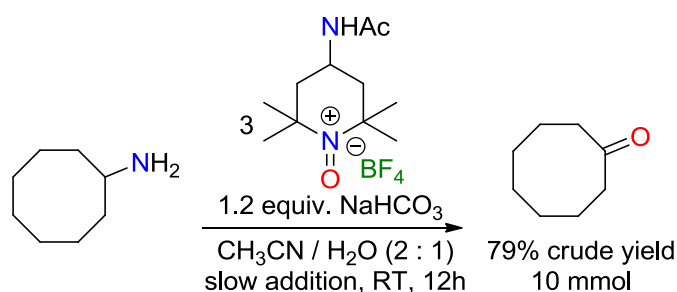


Scheme 2-26



Scheme 2-27

Due to the consumption of the oxoammonium salt oxidant in processes that involve the loss of ammonia as a result of this side reaction, such as the chemistry described above in Scheme 2-23, an excess of oxoammonium salt is necessary to ensure the desired oxidation proceeds efficiently. This chemistry impedes the development of amine oxidations to form carbonyl compounds as loss of ammonia is a required step. One example of this chemistry is shown below in Scheme 2-28. Even with the use of 3 molar equivalents of **1**, only a moderate 79% isolated yield is obtained from the oxidation of cyclooctylamine to cyclooctanone. More work needs to be done to optimize the reaction conditions.



Scheme 2-28

Chapter II References

- ¹ Selected examples: (a) Schumperli, M.T.; Hammond, C.; Hermans, I. *ACS Catal.* **2012**, 2, 1108–1117. (b) Rosenblatt, D. H.; Burrows, E. in *Supplement F: The Chemistry of Amino, Nitroso, and Nitro Compounds and Their Derivatives, Vol. 1* Part 2 (Ed.: S. Patai), Wiley, Chichester, **1982**, pp. 1085–1149. (c) Noller, C. R. in *Textbook of Organic Chemistry Vol. 3*, W. B. Saunders Company, Philadelphia, PA, **1966**, p. 229.
- ² Selected examples: (a) Smith, M. B. in *March's Advanced Organic Chemistry; Vol. 7*, Wiley, Hoboken, NJ, **2013**; p 1453. (b) Nicolaou, K. C.; Mathison, C. J. *Angew. Chem. Int. Ed.* **2005**, 44, 5992–5997. (c) Ghorbani-Vaghei, R.; Veisi, H. *Synthesis* **2009**, 945–950.
- ³ (a) Fleming, F. F.; Yao, L.; Ravikumar, P.C.; Funk, L.; Shook, B. C. *J. Med. Chem.* **2010**, 53, 7902–7917. (b) Zhou, L. Y.; Zhang, J. L.; Sun, S. L.; Ge, F.; Mao, S. Y.; Ma, Y.; Lui, Z. H.; Dai, Y. J.; Yuan, S. *J. Agric. Food Chem.* **2014**, 62, 9957–9964. (c) Collett, M. G.; Stegelmeier, B. L.; Tapper, B. A. *J. Agric. Food Chem.* **2014**, 62, 7370–7375.
- ⁴ Mowry, D. T. *Chem. Rev.* **1948**, 42, 189–283.
- ⁵ Fatiadi, A. J. *Preparation and Synthetic Applications of Cyano Compounds*, Wiley, New York, **1983**.
- ⁶ (a) Larock R. C. in *Comprehensive Organic Transformations, Vol. 1*, VCH Publishers, New York, **1989**, pp. 933. (b) Niemerier, J. K.; Rothhaar, R. R.; Vicenzi, J. T.; Werner, J. A. *Org. Process Res. Dev.* **2014**, 18, 410.
- ⁷ Lee, G. A. *Synthesis* **1982**, 6, 508–510.
- ⁸ Herzberger, J.; Frey, H. *Macromolecules* **2015**, 48, 8144–8153.
- ⁹ Smith, M. B. in *March's Advanced Organic Chemistry; Vol. 7*, Wiley and Sons, Hoboken, NJ, **2013**, pp. 1625–1626.
- ¹⁰ Smith, M. B. in *March's Advanced Organic Chemistry; Vol. 7*, Wiley and Sons, Hoboken, NJ, **2013**; pp. 562–564.
- ¹¹ Golubev, V. A.; Rozantzev, É. G.; Neiman, M. B. *Bull. Acad. Sci. USSR, Div. Chem. Sci.* **1965**, 14, 1898–1904.
- ¹² Hunter, D. H.; Racok, J. S.; Rey, A. W.; Zea-Ponce, Y. *J. Org. Chem.* **1988**, 53, 1278–1281.
- ¹³ Bobbitt, J. M.; Ma, Z. *Heterocycles* **1992**, 33, 641–648.
- ¹⁴ Bobbitt, J. M. *TCIMail* **2011**, 149, 2–10.
- ¹⁵ Semmelhack, M. F.; Schmid, C. R. *J. Am. Chem. Soc.* **1983**, 105, 6732–6734.
- ¹⁶ MacCorquodale, F.; Crayston, J. A.; Walton, J. C.; Worsfold, D. J. *Tetrahedron Lett.* **1990**, 31, 771–774.
- ¹⁷ Kashiwagi, Y.; Kurashima, F.; Kikuchi, C.; Anzai, J.; Osa, T.; Bobbitt, J. M. *J. Chin. Chem. Soc.* **1998**, 45, 135 – 138.
- ¹⁸ Hunter, D. H.; Barton, D. H. R.; Motherwell, W. J. *Tetrahedron Lett.* **1984**, 25, 603–606.
- ¹⁹ Kashiwagi, Y.; Anzai, J. *Chem. Pharm. Bull.* **2001**, 3, 324–326.
- ²⁰ Chen, F.; Kuang, Y.; Dai, H.; Lu, L.; Huo, M. *Synthesis* **2003**, 17, 2629–2631.
- ²¹ For a review see: Tilstam, U.; Weinmann, H. *Org. Process Res. Dev.* **2002**, 6, 384–393 and references therein.
- ²² Elsbernd, H.; Beattie, J. K. *J. Chem. Soc. (A)*, **1970**, 16, 2598–2600.
- ²³ McWhinnie, W. R.; Miller, J. D.; Watts, J. B.; Wadden, D. Y. *Chem. Commun.* **1971**, 12, 629–630.
- ²⁴ Lane, B. C.; Lester, J. E.; Basolo, F. *Chem. Commun.*, **1971**, 24, 1618–1619.
- ²⁵ Selected examples: (a) Diamond, S. E.; Tom, G. M.; Taube, H. *J. Am. Chem. Soc.* **1975**, 10, 2661–2664. (b) Schroder, M.; Griffith, W. P. *J. Chem. Soc., Chem. Commun.* **1979**, 2, 58–59. (c) Green, G.; Griffith, W. P.; Hollinshead, D. M.; Ley, S. V.; Schroder, M. *J. Chem. Soc. Perkin Trans.* **1984**, 1, 681–686. (d) Blum, Y.; Czarkle, D.; Rahamim, Y.; Shvo, Y. *Organometallics* **1985**, 8, 1459–1461. (e) Bailey, A. J.; James, B. R. *Chem. Commun.*, **1996**, 20, 2343–2344. (f) Griffith, W. P.; Reddy, B.; Shoir, A. G. F.; Suriaatmaja, M.; White, A. J. P.; Williams, D. *J. J. Chem. Soc. Dalton Trans.* **1998**, 17, 2819–2825. (g) Mori, K.; Yamaguchi, K.; Mizugaki, T.; Ebitani, K.; Kaneda, K. *Chem. Commun.* **2001**, 5, 461–462. (h) Samec, J. S.; Backvall, J. *Chem. Eur. J.* **2002**, 13, 2955–2961. (i) Yamaguchi, K.; Mizuno, N. *Chem. Eur. J.* **2003**, 9, 4353–4361. (j) Yamaguchi, K.; Mizuno, N. *Angew. Chem. Int. Ed.* **2003**, 42, 1480–1483. (k) Samec, J. S. M.; Ell, A. H.; Backvall, J. *Chem. Eur. J.* **2005**, 11, 2317–2334. (l) Kotani, M.; Kioke, T.; Yamaguchi, K.; Mizuno, N. *Green Chem.* **2006**, 8, 735–741. (m) Murahashi, S.; Okano, Y.; Sato, H.; Nakae, T.; Komiya, N. *Synlett* **2007**, 11, 1675–1678. (n) Li, F.; Chen, J.; Zhang, Q.; Wang, Y. *Green Chem.* **2008**, 10, 553–562. (o) Mizuno, N.; Yamaguchi, K. *Catal. Today* **2008**, 132, 18–26. (p) Yamaguchi, K.; Kim, J. W.; He, J.; Mizuno, N.; *J. Catal.* **2009**, 268, 343–349. (q) Taketoshi, A.; Koizumi, T.; Kanbara, T. *Tetrahedron. Lett.* **2010**, 51, 6457–6459. (r) Aiki, S.; Taketoshi, A.; Kuwabara, J.; Koizumi, T.; Kanbara, T. *J. Organomet. Chem.* **2011**, 696, 1301–1304. (s) Tseng, K. T.; Szymczak, N. K. *Synlett* **2014**, 25, 2385–2389. (t) Shoir, A. F.; El-Bindary, A. A. *Spectrochim. Acta Mol. Biomol. Spectrosc.* **2014**, 131, 490–496. (u) Ovoshchnikov, D. S.; Donoeva, B. G.; Golovko, V. B. *ACS Catal.* **2015**, 5, 34–38. (v) Shoir, A. G. F. *J. Mol. Liq.* **2015**, 206, 68–74.
- ²⁶ Goedken, V. L. *J. Chem. Soc., Chem. Commun.* **1972**, 4, 207–208.

- ²⁷ Selected examples: (a) Feldhues, U.; Schafer, H. J. *Synthesis* **1982**, 2, 145–146. (b) Yamazaki, S.; Yamazaki, Y. *Bull. Chem. Soc. Jpn.* **1990**, 63, 301–303.
- ²⁸ Zhao, S.; Liu, C.; Guo, Y.; Xiao, J.; Chen, Q. *J. Org. Chem.* **2014**, 79, 8926–8931.
- ²⁹ Selected examples: (a) Gu, X. Q.; Chen, W.; Morales-Morales, D.; Jensen, C. M. *J. Mol. Catal. A: Chem.* **2002**, 189, 119–124. (b) Bernskoetter, W. H.; Brookhart, M. *Organometallics* **2008**, 21, 2036–2045.
- ³⁰ Selected examples: (a) Capdevielle, P.; Lavigne, A.; Maumy, M. *Synthesis* **1989**, 6, 453–454. (b) Zhang, C.; Jino, N. *Angew. Chem. Int. Ed.* **2010**, 48, 6174–6177. (c) Damodara, D.; Arundhathi, R.; Likhari, P.R. *Adv. Synth. Catal.* **2014**, 356, 189–198. (d) Largeron, M.; Fleury, M. *Chem. Eur. J.* **2015**, 21, 3815–3820. (e) Zhan, L.; Han, L.; Xing, P.; Jing, B. *Org. Lett.* **2015**, 24, 5990–5993. (f) Patil, R. D.; Adimurthy, S. *Adv. Synth. Catal.* **2011**, 353, 1695–1700.
- ³¹ For detailed reviews see: (a) Ryland, B. L.; Stahl, S. S. *Angew. Chem. Int. Ed.* **2014**, 53, 8824–8838. (b) Cao, Q.; Dornan, L. M.; Rogan, L.; Hughes, N. L.; Muldoon, M. J. *Chem. Commun.* **2014**, 50, 4524–4543.
- ³² Hu, Z.; Kerton, F. M. *Org. Biomol. Chem.* **2012**, 10, 1618–1624.
- ³³ Sonobe, T.; Oisaki, K.; Kanai, M. *Chem. Sci.* **2012**, 3, 3249–3255.
- ³⁴ Huang, B.; Tian, H.; Lin, S.; Xie, M.; Yu, X.; Xu, Q. *Tetrahedron Lett.* **2013**, 54, 2861–2864.
- ³⁵ Kim, J.; Stahl, S. S. *ACS Catal.* **2013**, 3, 1652–1656.
- ³⁶ Lambert, K. M.; Bobbitt, J. M.; Eldirany, S. A.; Wiberg, K. B.; Bailey, W. F. *Org. Lett.* **2014**, 16, 6484–6487.
- ³⁷ (a) Bobbitt, J. M. *J. Org. Chem.* **1998**, 63, 9367–9374. (b) Mercadante, M. A.; Kelly, C. B.; Bobbitt, J. M.; Tilley, L. J.; Leadbeater, N. E. *Nat. Protoc.* **2013**, 8, 666–676.
- ³⁸ Computational studies for this work were conducted by Dr. Kenneth Wiberg of Yale University.
- ³⁹ Bailey, W. F.; Bobbitt, J. M.; Wiberg, K. B. *J. Org. Chem.* **2007**, 72, 4504–4509.
- ⁴⁰ Bobbitt, J. M.; Bartelson, A. L.; Bailey, W. F.; Hamlin, T. A.; Kelly, C. B. *J. Org. Chem.* **2014**, 79, 1055–1067.
- ⁴¹ Lambert, K. M.; Bobbitt, J. M.; Eldirany, S. A.; Kissane, L. E.; Sheridan, R. K.; Stempel, Z. D.; Sternberg, F. H.; Bailey, W. F. *Chem. Eur. J.* **2016**, 22, 5156–5159.
- ⁴² Bolm, C.; Magnus, A. S.; Hildebrand, J. P. *Org. Lett.* **2000**, 2, 1173–1175.
- ⁴³ Hussain, H.; Green, I. R.; Ahmed, I. *Chem. Rev.* **2013**, 113, 3329–3371.
- ⁴⁴ Rychnovsky, S. D.; Vaidyanathan, R. *J. Org. Chem.* **1999**, 64, 310–312.
- ⁴⁵ Fields, J. D.; Kropp, P. J. *J. Org. Chem.* **2000**, 65, 5937–5941.
- ⁴⁶ (a) Reagent grade CH_2Cl_2 containing < 0.01 % water was used as received and reagent grade pyridine was freshly distilled from CaH_2 just prior to use. (b) When present, the aldehyde by-product was removed by treatment of the crude product mixture with a commercially available aldehyde scavenger.
- ⁴⁷ Cioffi, E. A.; Bailey, W. F. *Tetrahedron Lett.* **1998**, 39, 2679–2680.
- ⁴⁸ Oxone[®] is a commercially available triple salt of empirical formula $2 \text{KHSO}_5 \cdot \text{KHSO}_4 \cdot \text{K}_2\text{SO}_4$, and has a combined molecular mass of 614.7 g/mol. Each molar quantity of the triple salt contains 2 moles of the terminal oxidant (KHSO_5), which has a molecular mass of 152.2 g/mol. The oxidation requires at least 2.0 equivalents of KHSO_5 to proceed, however, it is beneficial to use an excess as it simplifies the work-up process. The amount of Oxone[®] employed in this procedure is 26 mmol (16.0 g, 2.6 equiv.) per 10 mmol of amine substrate, and is arrived at by accounting for the fact that commercial Oxone[®] contains only 42–44 % by mass of the active component (KHSO_5). As a result, 6.70 g (44 mmol, 4.4 equiv. relative to the starting amine) of the terminal oxidant (KHSO_5) is present in the reaction mixture. This was calculated as follows:
 $10 \text{ mmol amine} \times 4.4 \text{ equiv.} = 44 \text{ mmol oxidant}$
 $0.044 \text{ mol KHSO}_5 \times (152.2 \text{ g KHSO}_5 / 1 \text{ mol KHSO}_5) = 6.70 \text{ g KHSO}_5$
 $6.70 \text{ g KHSO}_5 / 0.42 = 16.0 \text{ g Oxone}^{\text{®}}$
- ⁴⁹ While the reaction requires only 2.2 molar equivalents of oxone relative to the starting amine, 4.4 equivalents were employed. The surplus oxone oxidizes excess pyridine to pyridine-N-oxide upon stirring overnight. This substantially simplifies the work-up procedure as the pyridine-N-oxide is easily removed by filtration through a silica gel plug.
- ⁵⁰ (a) Macharla, A. K.; Nappunni, R. C.; Nama, N. *Tetrahedron Lett.* **2012**, 53, 1401–1405. (b) Wang, G. W.; Gao, J. *Green Chem.* **2012**, 14, 1125–1131.
- ⁵¹ Hawker, C. J.; Bosman, A. W.; Harth, E. *Chem. Rev.* **2001**, 101, 3661–3688.
- ⁵² Starks, C. M.; Liotta, C. L.; Halpern, M. in *Phase-Transfer Catalysis – Fundamentals, Applications, and Industrial Perspectives*, Chapman and Hall; New York, **1994**, pp. 508.
- ⁵³ Fieser, L. F.; Fieser, M. in *Advanced Organic Chemistry*, Reinhold Publishing Corporation; New York, **1961**, pp. 513.
- ⁵⁴ Sen, V. D.; Golubev, V. A. *J. Phys. Org. Chem.* **2009**, 22, 138–143.

- ⁵⁵ Kelly, C. B.; Lambert, K. M.; Mercadante, M. A.; Ovian, J. M.; Bailey, W. F.; Leadbeater, N. E. *Angew. Chem. Int. Ed.* **2015**, *127*, 4315–4319.
- ⁵⁶ Laulhé, S.; Gori, S. S.; Nantz, M. H. *J. Org. Chem.* **2012**, *77*, 9334–9337 and references therein.
- ⁵⁷ Kelly, C. B.; Mercadante, M. A.; Wiles, R. J.; Leadbeater, N. E. *Org. Lett.* **2013**, *15*, 2222–2225.
- ⁵⁸ The use of this analogue needs to be done carefully, and in most instances its use is strongly discouraged. See: Bobbitt, J. M. *Chem. Eng. News* **1999**, *77*, 6.
- ⁵⁹ Qui, J. C.; Pradhan, P. P.; Blanck, N. B.; Bobbitt, J. M.; Bailey, W. F. *Org. Lett.* **2012**, *14*, 350–353.
- ⁶⁰ At the time of publication, it was believed that there was no means to sequester the resulting BF₃ by-product, thus 1.1 molar equivalents of pyridine was added to accomplish this and prevent any side reactions. Mechanistically, the pyridine is unnecessary and its addition had no deleterious effects on the oxidation.
- ⁶¹ Miyazawa, T.; Endo, T.; Okawara, M.; *Synthesis* **1984**, *16*, 1034–1036.
- ⁶² Hagiwara, H.; Ono, H.; Komatsubara, N.; Hoshi, T.; Suzukia, T.; Ando M. *Tetrahedron Lett.* **1990**, *40*, 6627–6630.
- ⁶³ 2,6-Lutidine, was selected for this first step to suppress dimeric ester formation. The degree of dimeric ester formation can vary based on the structure of the aldehyde. See Ref. 40 as well as: Merbouh, N.; Bobbitt, J. M.; Brückner, C.; *J. Org. Chem.* **2004**, *69*, 5116–5119.
- ⁶⁴ (a) Lebedev, O. A.; Kazarnovskii, S. N. *Trudy po Khimii i Khim. Tekhnologii (Gorkii)* **1959**, *8*, 649. (b) Neiman, M. B.; Rozantsev, É. G.; Mamedova, Y. G. *Nature* **1962**, *196*, 472–474. (c) Rozantsev, É. G.; Neiman, M. B. *Tetrahedron*, **1964**, *20*, 131 – 137. (d) Briere, R.; Lemaire, H.; Rassat, A. *Bull. Soc. Chim. Fr.* **1965**, *32*, 3273 – 3283. (e) Kocherginsky, N.; Swartz, H. M. in *Nitroxide Spin Labels: Reactions in Biology and Chemistry*, CRC Press; New York, **1995**. (f) Ganem, B. *J. Org. Chem.* **1975**, *40*, 1998–2000. (g) Gimes, D.; Marque, S. R. A. in *Encyclopedia of Radicals in Chemistry, Biology, and Materials, Vol. 4.*, John Wiley and Sons; Hoboken, NJ, **2012**. (h) Tebben, L.; Studer, A. *Angew. Chem. Int. Ed.* **2011**, *50*, 5034–5068.
- ⁶⁵ For a review of nitroxides see: (a) Keana, J. F. W. *Chem. Rev.* **1978**, *78*, 37–67. (b) Bobbitt, J. M.; Brückner, C.; Merbouh, N. *Org. React. (NY)* **2010**, *74*, 103–424 and references therein. (c) Naik, N.; Braslau, R. *Tetrahedron*, **1998**, *54*, 667–696.
- ⁶⁶ (a) Nilsen, A.; Breslau, R. *J. Polym. Sci. A Polym. Chem.* **2005**, *44*, 697–717. (b) Breuer, E., Aurich, H. G.; Nielsen, A. in *Nitrones, Nitronates, and Nitroxides*, Wiley, New York, **1989**.
- ⁶⁷ (a) Dupeyre, R.-M.; Rassat, A. *J. Am. Chem. Soc.* **1966**, *88*, 3180 (b) Dupeyre, R.-M.; Rassat, A. *Tetrahedron*, **1978**, *34*, 1901.
- ⁶⁸ (a) Shibuya, M.; Tomizawa, M.; Suzuki, I.; Iwabuchi, Y. *J. Am. Chem. Soc.* **2006**, *128*, 8412–8413. (b) Iwabuchi, Y. *J. Synth. Org. Chem. Jpn.* **2008**, *66*, 1076. (c) Shibuya, M.; Tomizawa, M.; Sasano, Y.; Iwabuchi, Y. *J. Org. Chem.* **2009**, *74*, 4619–4622. Tomizawa, M.; Shibuya, M.; Iwabuchi, Y. *Org. Lett.* **2009**, *11*, 1829–1831. (d) Yamakoshi, H.; Shibuya, M.; Tomizawa, M.; Osada, Y.; Kanoh, N.; Y. Iwabuchi *Org. Lett.* **2010**, *12*, 980–983.
- ⁶⁹ Amar, M.; Bar, S.; Iron, M. A.; Toledo, H.; Tumanskii, B.; Shimon, L. J. W.; Botoshansky, M.; Fridman, N.; Szpilman, A. M. *Nat. Commun.* **2015**, *6*, 6070.
- ⁷⁰ Gryn'ova, G.; Barakat, J. M.; Blinco, J. P.; Bottle, S. E.; Coote, M. L. *Chem. Eur. J.* **2012**, *18*, 7582–7593.
- ⁷¹ Kavala, M.; Brezová, V.; Švorc, L.; Vihonská, Z.; Olejníková, P.; Moncol, J.; Kožíšek, J.; Herich, P.; Szolcsányi, P. *Org. Biomol. Chem.* **2014**, *12*, 4491–4502.
- ⁷² Hickey, D. P.; Schiedler, D. A.; Matanovic, I.; Doan, P. V.; Atanassov, P.; Minter, S. D.; Sigman, M. A. *J. Am. Chem. Soc.* **2015**, *137*, 16179–16186.
- ⁷³ For a review of oxoammonium salt oxidations see reference 65b along with: (a) Bobbitt, J. M.; Flores, C. L. *Heterocycles* **1988**, *27*, 509–533. (b) Merbouh, N.; Bobbitt, J. M.; Brückner, C. *Org. Prep. Proced. Int.* **2004**, *36*, 1–31 and references therein.
- ⁷⁴ Ma, Y. Nitroxides in Mechanistic Studies: Ageing of Gold Nanoparticles and Nitroxide Transformations in Acids. PhD thesis, University of York, **2010**.
- ⁷⁵ Bobbitt, J. M. *J. Org. Chem.* **1998**, *63*, 9367–9374.
- ⁷⁶ The most economical price found from major chemical suppliers for 2,2,6,6-tetramethylpiperidine was \$449.00 / 250 mL ~ \$339 / mol (U. S. Dollars) from TCI America.
- ⁷⁷ The most economical price found from major chemical suppliers for 4-amino-2,2,6,6-tetramethylpiperidine was \$337.00 / 500 mL ~ \$118 / mol (U. S. Dollars) from TCI America.
- ⁷⁸ Lantzs, R.; Arlt; D. (Bayer Aktiengesellschaft). Process for preparing 4-amino-2,2,6,6-tetramethylpiperidine. U.S. Patent 4,001,250, February 24, 1975.
- ⁷⁹ Mercadante, M. A.; Kelly, C. B.; Bobbitt, J. M.; Tilley, L. J.; Leadbeater, N. E. *Nat. Protoc.* **2013**, *8*, 666–676.

- ⁸⁰ The perchlorate anion should be avoided and its use is not recommended as it has been found to be thermally unstable; see: Bobbitt, J. M. *Chem. Eng. News* **1999**, 77, 6.
- ⁸¹ Rafiee, M.; Miles, K. C.; Stahl, S. S. *J. Am. Chem. Soc.* **2015**, 137, 14751–14757.
- ⁸² Miyazawa, T.; Endo, T.; Okawara, M. *J. Org. Chem.* **1985**, 50, 5389–5391.
- ⁸³ Tojo, G.; Fernández, M. I. *Oxidation of Alcohols to Aldehydes and Ketones: A Guide to Current Common Practice*, Springer; New York, **2006**, p. 244.
- ⁸⁴ Blanco, M.; Iturriaga, H.; MasPOCH, S.; Tarín, P. *J. Chem. Ed.* **1989**, 66, 178–180.
- ⁸⁵ Harris, D. C. in *Quantitative Chemical Analysis*, 8th Ed., W. H. Freeman and Company; New York, **2010**, pp. 419–425.
- ⁸⁶ The absorbance values of the standard were taken from the average of five individual readings of the same standard solution.
- ⁸⁷ This refers to every 10 nm from 370–530nm.
- ⁸⁸ The spectrophotometer used was a Cary 60 from Agilent Technologies (version 2.00) scanning from 550–350 nm at a rate of 4600 or 9600 nm/min.
- ⁸⁹ The baseline was corrected to account for any residual absorbance from the acetonitrile solvent by running a blank with the dry acetonitrile solvent before initiating the oxidation.
- ⁹⁰ Cinnamyl was the fastest oxidized substrate investigated with a half-time of 2.60 s with **5**. Whereas, neopentyl alcohol was the slowest oxidized substrate tested with a half-time of 2.00 h with **5**.
- ⁹¹ Golubev, V. A.; Borislavskii, V. N.; Aleksandrov, A. L. *Russ. Chem. Bull.* **1977**, 26, 1874–1881.
- ⁹² Hamlin, T. A.; Kelly, C. B.; Ovia, J. M.; Wiles, R. J.; Tilley, L. J.; Leadbeater, N. E. *J. Org. Chem.* **2015**, 80, 8150–8167.
- ⁹³ (a) Hammett, L. P. *Chem. Rev.* **1935**, 17, 125. (b) Jaffé, H. H. *Chem. Rev.* **1953**, 53, 191.
- ⁹⁴ The Hammett plot shown in Figure 2-13 depicts the result of taking the logarithm of the rate oxidation for the substituted benzyl alcohol (K_X) relative to the rate of oxidation of benzyl alcohol (K_{BA}) and comparing it to the Hammett σ -parameters defined from substituted benzoic acids. See Refs. 93 and 95.
- ⁹⁵ Mukherjee, J.; Banerji, K. K. *J. Chem. Soc., Perkin Trans. 2* **1980**, 676–678.
- ⁹⁶ Substrates chosen for this portion were limited to small secondary alcohols that are fairly water soluble as over-oxidation to a carboxylic acid occurs with primary alcohols under aqueous conditions. See ref. 60.
- ⁹⁷ Robertson, G. M. Imines and Their N-Substitution Derivatives: NH, NR and N-Haloimines. In *Comprehensive Organic Functional Group Transformations*; Katritzky, A. R., Meth-Cohn, O., Rees, C. W., Eds.; Elsevier Science Ltd.: Tarrytown, NY, 1995; Vol. 3, pp 403–424.
- ⁹⁸ Abdel-Magid, A.; Carson, K. G.; Harris, B. D.; Maryanoff, C. A.; Shah, R. D. *J. Org. Chem.* **1996**, 61, 3849–3862.
- ⁹⁹ (a) Golubev, V. A.; Kobylanskii, E. V. *Zh. Org. Khim.* **1972**, 8, 2607–2613. (b) Semmelhack, M. F.; Schmid, C. R.; Cortés, D. A. *Tetrahedron Lett.* **1986**, 27, 1119–1122.
- ¹⁰⁰ Lee, T. D.; Keana, J. F. W. *J. Org. Chem.* **1975**, 40, 3145–3147.
- ¹⁰¹ Mishra, H. P.; Fridovich, I. *Biochemistry* **1976**, 15, 681–687.
- ¹⁰² Schirmann, J.-P. and Bourdauducq, P. Hydrazine. In *Ullmann's Encyclopedia of Industrial Chemistry* [Online]; Elvers, B., Ed.; Wiley-VCH: Germany, 2001; Vol. 18, pp 79–96.
- http://onlinelibrary.wiley.com/doi/10.1002/14356007.a13_177/abstract (accessed May 12, 2017).

CHAPTER III. EXPERIMENTAL SECTION FOR PART I.

3.1 Stoichiometric Oxidation of Primary Amines to Nitriles Using an Oxoammonium Salt¹

General Considerations

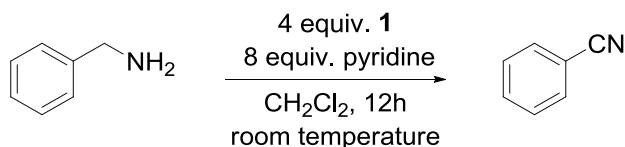
All reactions were carried out under a nitrogen or argon atmosphere in oven-dried and subsequently flame-dried glassware. The digital syringe pump used to deliver amine solutions was calibrated prior to use. Thin-layer chromatography was performed on Baker-flex (J.T. Baker) Silica Gel IB-F plates, and visualized using ultraviolet light (254 nm). Silica gel (40-63 μm particle size) utilized in chromatography was purchased from Dynamic Adsorbents Inc. NMR spectra (^1H , ^{13}C , ^{19}F) were recorded in CDCl_3 unless otherwise specified on a Brüker DRX-400 400 MHz NMR spectrometer and chemical shifts are reported in parts per million (ppm). Proton and carbon spectra were referenced at $\delta = 7.26$ and 77.23, respectively, for the residual ^1H resonance of the solvent and the center line of the ^{13}C adsorption of CDCl_3 and are reported relative to TMS at $\delta = 0.00$. Fluorine spectra were recorded in CDCl_3 using fluorobenzene as an internal standard ($\delta = -113.15$); chemical shifts are reported relative to CCl_3F at $\delta = 0.00$. All of the nitriles synthesized in this study are known compounds whose ^1H NMR and ^{13}C NMR spectra were fully in accord with those reported in the literature. All calculations were done using Gaussian 09 software² at the B3LYP/6-311+G* level. Figures were generated utilizing CYLView software.³

Reagents

Deuterated NMR solvents (CDCl_3 , $\text{DMSO}-d_6$) were purchased from Cambridge Isotope Laboratories. CDCl_3 was stored over 4 Å molecular sieves. Fluorobenzene was purchased from ACROS. Sodium sulfate, pyridine, dimethylformamide, methanol, ethanol, dichloromethane, and diethyl ether (ACS Grade and reagent grade) were purchased from Sigma-Aldrich. Anhydrous dichloromethane was obtained by distillation from calcium hydride immediately prior to use. Pyridine was dried over activated 4 Å molecular sieves. A literature procedure, incorporating some minor modifications, was used to prepare cinnamylamine.⁴ Bobbitt's salt (**1**) was prepared following the reported procedure.⁵ Prior to use,

a slurry of the oxoammonium salt was stirred for 12 h in dichloromethane, filtered, and dried overnight at 60 °C (1 mm) in a vacuum oven. Silabond[®] Amine, used as an aldehyde scavenger was purchased from Silicycle Inc.

Representative Procedure for Stoichiometric Amine Oxidations to Nitriles



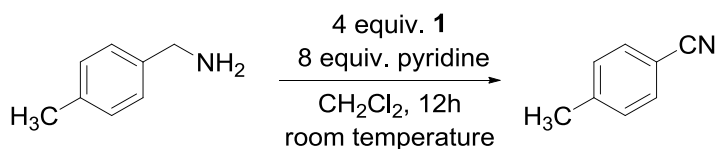
Benzonitrile^{6,7} (Table 2-4, entry 1) To a flame-dried, nitrogen/argon flushed, 250-mL round bottom flask containing a magnetic stir bar was added 12.06 g (40 mmol) of 4-acetamido-2,2,6,6-tetramethylpiperidine-1-oxoammonium tetrafluoroborate (**1**), 150 mL of dry dichloromethane (distilled from calcium hydride just prior to use), and 6.33 g (80 mmol) of dry pyridine. A solution of benzylamine (1.070 g, 10 mmol) in 20 mL of dry dichloromethane (0.5 M) was then added by syringe pump at a rate of 20 mL per hour. The reaction, which was monitored by following the colorimetric changes noted above, was stirred at room temperature for 12 hours. The majority of the solvent was removed at room temperature on a rotary evaporator and 100 mL of diethyl ether was added to the resulting slurry. The mixture was stirred for 20 minutes to precipitate nitroxide **2**, filtered through coarse filter paper directly into a separatory funnel, and the flask was rinsed with two additional 25-mL portions of diethyl ether. As detailed below, nitroxide **2** may be recovered from the solid residue consisting of impure **2** and pyridinium tetrafluoroborate, and this material may be used to regenerate **1**. The light orange ethereal solution was washed at least five times with 50-mL portions of 10 % aqueous hydrochloric acid solution until the aqueous layer remained clear. The organic layer was rinsed with 50 mL of saturated brine, dried over sodium sulfate, and filtered into a round bottom flask. The solution was concentrated under reduced pressure until ~ 10 mL remained to which 250–500 mg of SilaBond[®] Amine was added. The mixture was stirred for 1 hour to remove any aldehyde byproduct (typically 0–10% of aldehyde was generated due to residual moisture). The mixture was filtered through a pipette containing 0.500 g of silica gel using a 50% Et₂O/pentane solution as an eluent. The solvent was removed to afford 0.946 g (91%) of the title

compound as a light yellow oil: ^1H NMR (400 MHz, CDCl_3) δ 7.50–7.61 (m, 3H), 7.40–7.45 (m, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 132.8, 132.0, 129.1, 128.8, 117.6, 112.3.

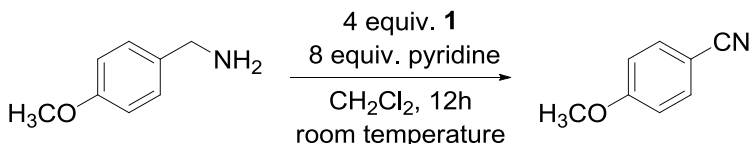
Procedure for Recovery of Nitroxide (2) and Regeneration of Oxoammonium Salt (1)

Nitroxide **2** may be recovered from the orange/white precipitate consisting of impure nitroxide **2** and pyridium tetrafluoroborate (generally 12–14 g per 10 mmol reaction). This solid residue is suspended in dichloromethane (~ 10 mL per 1 g of precipitate) and stirred for 10 minutes. The dark-red solution was filtered through a sintered-glass funnel, and the filtrate was concentrated by rotary evaporation to afford crude nitroxide **2** as an orange solid, mp 134.5–137.5 °C (lit. mp 144–146 °C)⁴. The recovery was typically 70–80%. The nitroxide **2** recovered in this way can be used to regenerate oxoammonium salt **1** as previously described.⁵

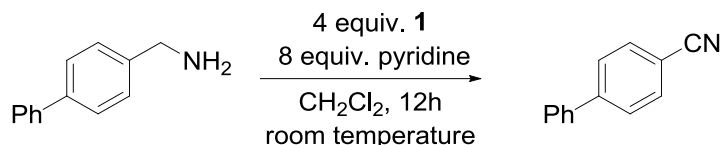
Preparation and Characterization of Nitriles



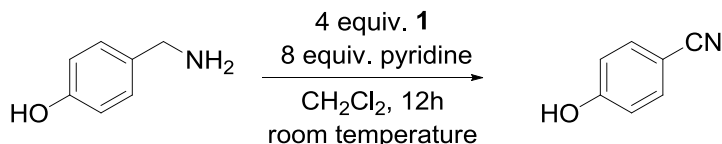
4-Methylbenzonitrile⁸ (Table 2-4, entry 2); Was prepared as in the representative procedure from 4-methylbenzylamine (1.210 g, 10 mmol) to yield 1.095 g (94 %) of the title compound as a white solid: mp 24.8–25.9 °C (lit. 26–28 °C); ^1H NMR (400 MHz, CDCl_3) δ 7.52 (d, J = 8.0 Hz, 2H), 7.25 (d, J = 7.9 Hz, 2H), 2.41 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 143.8, 132.2, 130.0, 119.3, 109.5, 22.0.



4-Methoxybenzonitrile^{8,9} (Table 2-4, entry 3); Was prepared as in the representative procedure from 4-methoxybenzylamine (1.370 g, 10 mmol) to afford 1.114 g (86%) of the title compound. The product was easily recrystallized from a minimal amount of pentane to yield a white solid: mp 56.8–57.6 °C (lit. 57–58 °C); ^1H NMR (400 MHz, CDCl_3) δ 7.56 (d, J = 8.9 Hz, 2H), 6.93 (d, J = 8.9 Hz, 2H), 3.84 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 163.0, 134.1, 119.4, 114.9, 104.1, 55.7.

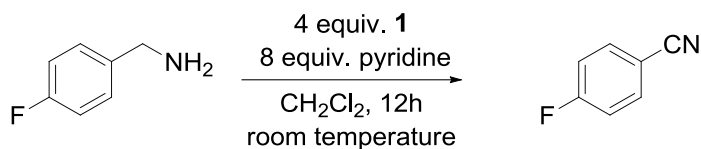


4-Phenylbenzonitrile¹⁰ (Table 2-4, entry 4); Was prepared as in the representative procedure from 4-phenylbenzylamine (1.802 g, 9.8 mmol) with the following modifications. It was necessary to use a 0.25 M solution of the amine in 40 mL of dichloromethane due to the limited solubility of the substrate. During the first aqueous washing, 25 mL of methanol was added to ensure the complete solubility of the product in the organic layer. **NOTE:** *If this step is not performed, a heterogeneous emulsion forms due to product insolubility and the overall yield suffers (\approx 59%).* The rest of the work-up is performed in the normal way to yield 1.593 g (90%) of the title compound as a white solid: mp 82.8–83.9 °C (lit. 84–85 °C); ¹H NMR (400 MHz, CDCl₃) δ 7.71 (dd, J = 16.8 Hz, 7.4 Hz, 4H), 7.59 (d, J = 7.8 Hz, 2H), 7.42–7.51 (m, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 145.9, 139.4, 132.8, 129.3, 128.9, 127.9, 127.4, 119.1, 111.1.

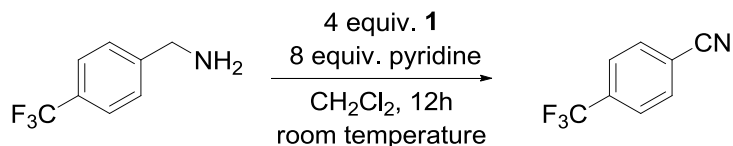


4-Hydroxybenzonitrile¹¹ (Table 2-4, entry 5); Was prepared as in the representative procedure from 4-hydroxybenzylamine (1.230 g, 10 mmol) with the following modifications. Due to the limited solubility of the amine in methylene chloride it was necessary to dissolve the amine in 16 mL of dichloromethane containing \sim 3 mL of pyridine. The amine solution was added at the usual rate of 20 mL per hour. After removal of the dichloromethane, 200 mL of ether was added to the slurry rather than the 100 mL typically used. The solids collected on the filter paper were washed with 10 mL of a 10% aqueous hydrochloric acid solution to ensure transfer of the phenol to the separatory funnel. From this point, the isolation procedure is the same as described above and affords 1.018 g (86%) of the title compound as a white solid: mp 109.7–111.6 °C (lit. 109–110 °C); ¹H NMR (400 MHz, DMSO-*d*₆) δ 10.57 (s, 1H), 7.57 (d, J =

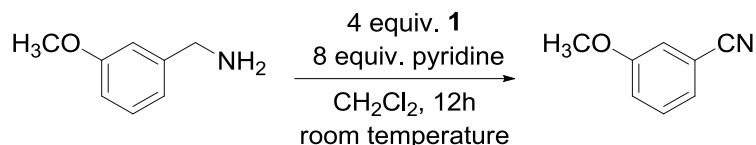
8.6 Hz, 2H) 6.89 (d, J = 8.6 Hz, 2H); ^{13}C NMR (100 MHz, $\text{DMSO}-d_6$) δ 161.7, 134.2, 119.6, 116.5, 101.2.



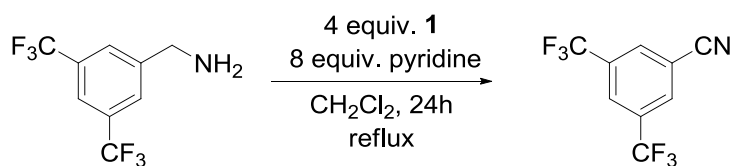
4-Fluorobenzonitrile^{12,13} (Table 2-4, entry 6); Was prepared as in the representative procedure from 4-fluorobenzylamine (1.250 g, 10 mmol). **NOTE:** *The title compound readily sublimes under gentle warming at reduced pressure (≈ 30 °C at 20 mm), thus careful removal of the solvent at a temperature no greater than 25 °C is necessary to limit loss of product.* Careful work-up yields 0.883 g (73%) of the title compound as a white solid: mp 36.3–37.1 °C (lit. 35–36 °C); ^1H NMR (400 MHz, CDCl_3) δ 7.66 (dd, J = 5.2 Hz, J = 9 Hz, 2H), 7.15 (t, J = 8.6 Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 165.1 (d, $J_{\text{C,F}}$ = 256.8 Hz), 134.8 (d, $J_{\text{C,F}}$ = 9.4 Hz), 118.1, 117.0 (d, J = 22.8 Hz), 108.7 (d, $J_{\text{C,F}}$ = 3.5 Hz); ^{19}F NMR (376 MHz, CDCl_3) δ –102.5.



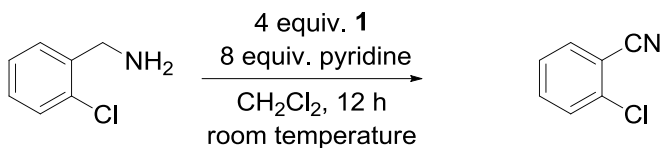
4-(Trifluoromethyl)benzonitrile^{14,15} (Table 2-4, entry 7); Was prepared as in the representative procedure from 4-(trifluoromethyl)benzylamine (1.751 g, 10 mmol) with the following modifications. A 0.5 M solution of the amine in dichloromethane was added at a rate of 15 mL per hour to the reaction mixture. After stirring for 24 hours at room temperature the reaction was worked-up in the normal way. The white solid product was easily recrystallized from a minimal amount of pentane to yield 1.522 g (89%) of the title compound as a colorless solid: mp 34.8–36.0 °C (lit. 36–37 °C); ^1H NMR (400 MHz, CDCl_3) δ 7.75 (d, J = 8.3 Hz, 2H), 7.81 (d, J = 8.3 Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 134.7 (q, $J_{\text{C,F}}$ = 33.1 Hz), 132.9, 126.3 (q, $J_{\text{C,F}}$ = 3.6 Hz), 123.0 (q, $J_{\text{C,F}}$ = 273 Hz), 117.6, 116.3; ^{19}F NMR (376 MHz, CDCl_3) δ –63.6.



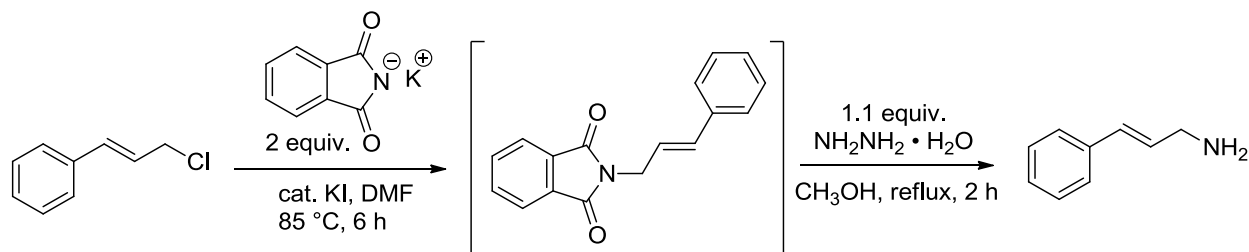
3-Methoxybenzonitrile¹⁶ (Table 2-4, entry 8); Was prepared from 3-methoxybenzylamine (1.371 g, 10 mmol) as in the representative procedure to yield 1.161 g (87%) of the title compound as a clear oil: ¹H NMR (400 MHz, CDCl₃) δ 7.32-7.37 (t, *J* = 8.3 Hz, 1H), 7.20 (d, *J* = 7.6 Hz, 1H), 7.10–7.11 (m, 2H), 3.80 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 130.4, 124.5, 119.3, 118.8, 116.9, 113.2, 55.6.



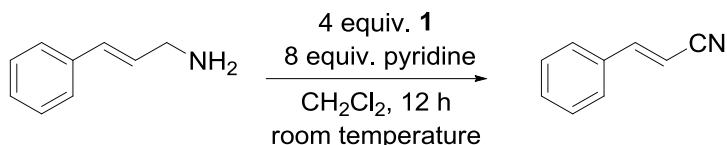
3,5-Bis(trifluoromethyl)benzonitrile¹⁷ (Table 2-4, entry 9); Was prepared as in the representative procedure from 3,5-bis(trifluoromethyl)benzylamine (2.436 g, 10 mmol) with the following modifications. A 0.5 M solution of the amine was added at a rate of 15 mL per hour and the reaction mixture was heated at reflux for 24 hours. After cooling the reaction mixture to room temperature, it was worked-up as described above, with the following exception: the product was purified by distillation (Kugelrohr, bath temperature: 75°C at 10 mm). The clear distillate was taken up in 10 mL of ether and stirred with 500 mg of SilaBond[®] Amine overnight. The mixture was filtered through a pipette containing 0.500 g of silica gel using a 50% ether/pentane solution as an eluent. Upon removal of the solvent under reduced pressure 1.789 g (75%) the title compound is afforded as a colorless liquid: ¹H NMR (400 MHz, CDCl₃) δ 8.14 (s, 2H), 8.12 (s, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 133.5 (q, *J*_{C,F} = 35.0 Hz), 132.5 (q, *J*_{C,F} = 2.8 Hz), 126.6 (br sxt, *J*_{C,F} = 3.1 Hz), 122.4 (q, *J*_{C,F} = 273 Hz), 116.1, 115.2; ¹⁹F NMR (376 MHz, CDCl₃) δ −63.4.



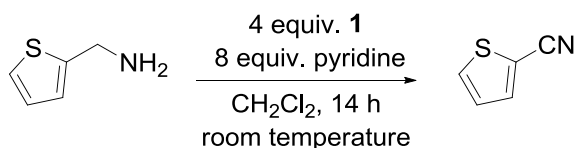
2-Chlorobenzonitrile^{18,19} (Table 2-4, entry 10); Was prepared as in the representative procedure from 2-chlorobenzylamine (1.416 g, 10 mmol) to yield 1.234 g (90%) of the title compound as a white solid: mp 42.0–43.0 °C (lit. 43–44 °C); ¹H NMR (400 MHz, CDCl₃) δ 7.63 (d, *J* = 7.9 Hz, 1H), 7.46–7.55 (m, 2H), 7.36 (t, *J* = 7.5 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 136.8, 134.0, 130.1, 127.3, 116.0, 113.3.



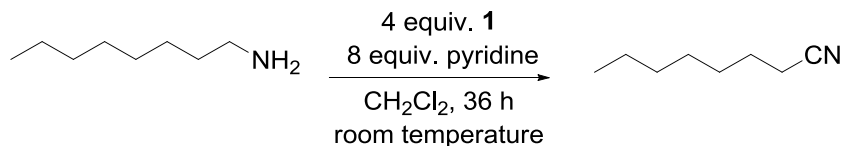
Cinnamylamine⁴; Cinnamyl chloride (5.00 g, 32.7 mmol), potassium phthalimide (12.14 g, 65.5 mmol), a catalytic amount of potassium iodide, and 30 mL of dimethylformamide was stirred under a nitrogen atmosphere and heated at 85 °C for 6 hours. The reaction was worked-up as described by Moody et al.⁴ to yield 7.46 g of *N*-cinnamylphthalimide, as a pale white solid. The crude *N*-cinnamylphthalimide and hydrazine monohydrate (1.56 g, 31.2 mmol) dissolved in 125 mL of methanol heated at reflux for two hours. The reaction was worked-up as described in the referenced procedure,⁴ and the yellow oil was distilled (Kugelrohr, bath temperature: 155 °C at 10 mm) to yield 2.86 g (66%, over 2 steps) of the title compound as a clear oil: ¹H NMR (400 MHz, CDCl₃) δ 7.35 (d, *J* = 7.3 Hz, 2H), 7.29 (t, *J* = 7.3, 2H), 7.20 (t, *J* = 7.3, 1H), 6.48 (d, *J* = 15.5 Hz, 1H) 6.25–6.33 (m, 1H) 3.44 (bs, 2H), 1.22 (s, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 137.2, 131.4, 129.3, 128.5, 127.2, 126.2, 44.3.



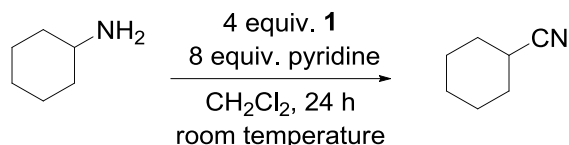
Cinnamonitrile²⁰ (Table 2-4, entry 11); Was prepared following the representative procedure from cinnamyl amine (1.330 g, 10 mmol). The crude yellow oil was purified by distillation (Kugelrohr, bath temperature: 140 °C at 10 mm) to yield 1.178 g (91%) of the title compound as a colorless oil: ¹H NMR (400 MHz, CDCl₃) δ 7.37–7.46 (m, 6H), 5.87 (d, *J* = 16.6 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 150.8, 133.8, 131.4, 129.3, 127.6, 118.4, 96.6.



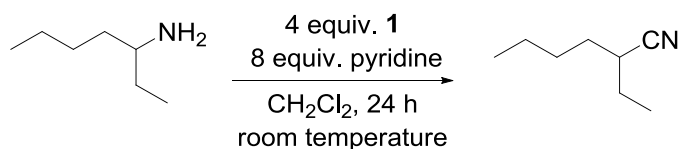
2-Thiophenecarbonitrile²¹ (Table 2-4, entry 12); Was prepared from 2-thiophenemethylamine (1.130 g, 10 mmol) as stated in the representative procedure with the following modification: The reaction mixture was stirred for 14 hours at room temperature. Isolation yielded 0.988 g (92%) the title compound as a light yellow oil: ¹H NMR (400 MHz, CDCl₃) δ 7.58–7.60 (m, 2H), 7.09–7.13 (m, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 137.5, 132.8, 127.7, 114.3, 109.8.



Octanenitrile²² (Table 2-4, entry 13); Was prepared following the representative procedure from octylamine (1.294 g, 10 mmol) with the following modifications: a 0.5 M solution of the amine in dichloromethane was added at a rate of 15 mL per hour and the reaction mixture was stirred for 36 hours at room temperature. The solvent was removed to yield 1.158 g (93%) of the title compound as a yellow oil: ¹H NMR (400 MHz, CDCl₃) δ 2.28 (t, *J* = 7.1 Hz, 2H), 1.60 (quint, *J* = 7.2 Hz, 2H) 1.39 (quint, *J* = 7.1 Hz, 2H) 1.24–1.28 (m, 6H) 0.83 (t, *J* = 6.3Hz, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 119.8, 31.5, 28.6, 28.4, 25.4, 22.5, 17.0, 14.0.



Cyclohexanecarbonitrile¹⁹ (Table 2-4, entry 14); Was prepared following the representative procedure from methylcyclohexylamine (1.130 g, 10 mmol) with the following modifications: A 0.5 M solution of the amine in dichloromethane was added at a rate of 15 mL per hour, and the resulting mixture was stirred for 24 hours at room temperature. The solvent was removed to yield 1.036 g (95%) of the title compound as a clear oil: ¹H NMR (400 MHz, CDCl₃) δ 2.55–2.60 (m, 1H), 1.76–1.80 (m, 2H), 1.60–1.70 (m, 4H), 1.37–1.49 (m, 4H); ¹³C NMR (100 MHz, CDCl₃) δ 122.6, 29.5, 27.9, 25.3, 24.0.



2-Ethylhexanenitrile²⁰ (Table 2-4, entry 15); Was prepared as in the representative procedure from 2-ethylhexylamine (1.292 g, 10 mmol) with the following modifications. A 0.5 M solution of the amine in dichloromethane was added at a rate of 15 mL per hour and the reaction mixture was stirred at room temperature for 24 hours. The solvent was removed to yield 1.040 g (83%) of the title compound as a light yellow oil: ¹H NMR (400 MHz, CDCl₃) δ 2.41 (m, 1H), 1.21–1.62 (m, 8H) 1.03 (t, *J* = 7.4 Hz, 2H) 0.87 (t, *J* = 7.1 Hz, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 122.2, 33.4 , 31.7, 29.3, 25.6, 22.3, 13.8, 11.6.

Figure 3-1

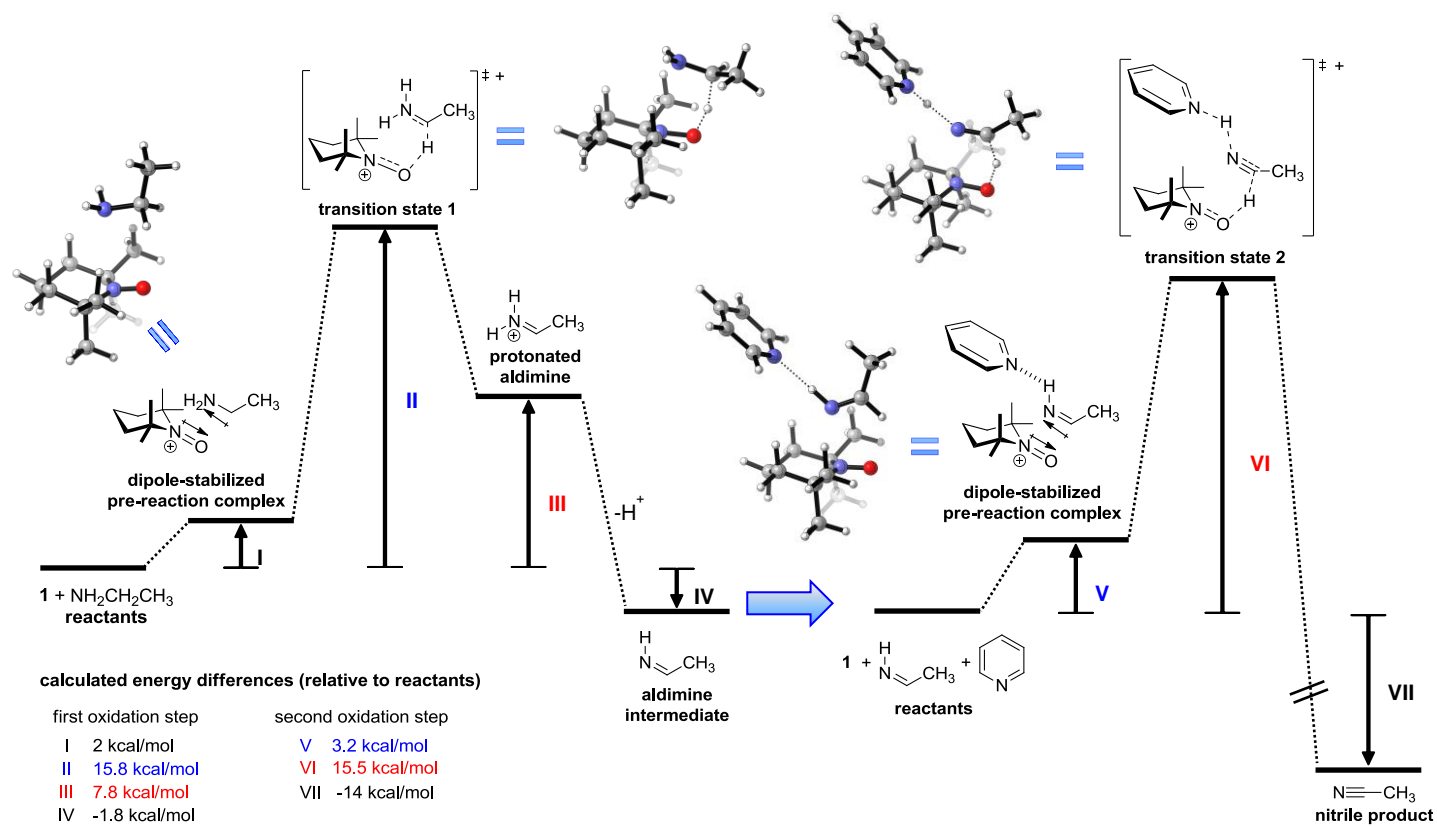


Table 3-1 Calculated Total Energies for Figure 2-3

Compound	E (H)	E(0) (H)	E(298) (H)	H(298) (H)	G(298) (H)
Oxoammonium Salt	-483.57595	-483.31287	-483.30085	-483.29991	-483.34906
Ethylamine	-135.20865	-135.11587	-135.11146	-135.11052	-135.14138
Pyridine	-248.34294	-248.25447	-248.25019	-248.24924	-248.28188
Acetaldimine	-133.98934	-133.92086	-133.91693	-133.91598	-133.94576
CH ₃ CH=NH ₂ ⁺	-134.34665	-134.26416	-134.26010	-134.25916	-134.28124
MeCNH ⁺	-133.09548	-133.03951	-133.03555	-133.03461	-133.06375
N-hydroxylamine	-484.43410	-484.16069	-484.14869	-484.14774	-484.19679
Pyridinium ion	-248.70793	-248.60511	-248.60073	-248.59978	-248.63260
MeCN	-132.79194	-132.74660	-132.74299	-132.74205	-132.76957
Calculated Total Energies for 1st Oxidation					
Reactants- Ethyl Amine, Oxoammonium Salt	-618.78460	-618.42874	-618.41231	-618.41043	-618.49044
Initial Complex	-618.79803	-618.44046	-618.42220	-618.42126	-618.48718
Simple Transition State	-618.77577	-618.42287	-618.40600	-618.40506	-618.46523
Calculated Total Energies for 2nd Oxidation					
3 Reactants - Acetaldimine, Pyridine, Oxoammonium Salt	-865.90823	-865.48820	-865.46797	-865.46513	-865.57670
Initial Complex	-865.94097	-865.51731	-865.49413	-865.49319	-865.57165
2nd Transition State	-617.53241	-617.20274	-617.18641	-617.18546	-617.24417
2nd Transition State with Pyridine	-865.91908	-865.49977	-865.47762	-865.47667	-865.55204

Table 3-2 Calculated Energy Differences for the Oxidative Process

Calculated Energy Differences for 1st Oxidation					
	E (kcal/mol)	E(0) (kcal/mol)	E(298) (kcal/mol)	H(298) (kcal/mol)	G(298) (kcal/mol)
Initial Complex Step 1	-8.4	-7.4	-6.2	-6.8	2.0
Step 1 Activation Energy from Reactants	5.5	3.7	4.0	3.4	15.8
Step 1 Activation Energy from Initial Complex	14.0	11.0	10.2	10.2	13.8
Overall Energy of 1st Oxidation without Pyridine from Reactants ($\text{CH}_3\text{CH}=\text{NH}_2^+$ product)	2.4	2.4	2.2	2.2	7.8
Overall Energy of 1st oxidation with Pyridine from Reactants (Acetaldimine product)	-2.4	-2.2	-2.4	-2.4	-1.8
Calculated Energy Differences for 2nd Oxidation					
Initial Complex Step 2	-20.5	-18.3	-16.4	-17.6	3.2
Activation Energy from 3 Reactants	20.6	19.4	19.7	19.1	31.8
Activation Energy from 3 Reactants with Pyridine	6.8	-7.3	-6.1	-7.2	15.5
Activation Energy from Initial Complex	13.7	11.0	10.4	10.4	12.3
Overall Energy of 2nd Oxidation without Pyridine from 3 Reactants (CH_3CNH^+ product)	22.4	21.0	21.0	21.0	21.5
Energy of a proton transfer from MeCNH^+ to Pyridine	-38.6	-36.2	-36.4	-36.4	-35.5
Overall Energy of 2nd Oxidation without Pyridine from 3 Reactants (MeCN product)	-16.2	-15.2	-15.3	-15.3	-14.0

Figure 3-2 Optimized geometries of the **Pre-reaction complex** leading to **Transition state 1** as shown in Figure 3-1.

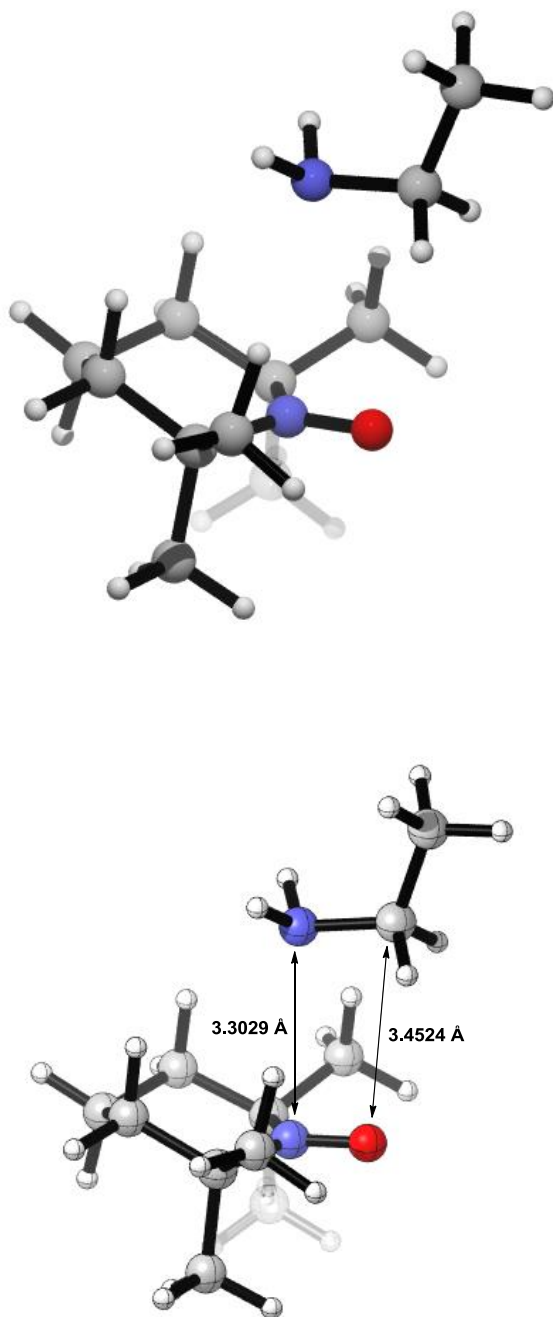


Table 3-3 Geometric Connectivity of Figure 3-2 - Oxoammonium Cation and Ethyl Amine Initial

Complex Step 1

opt rb3lyp/6-311+g(d)

Atom	X	Y	Z
1 1			
C	-1.16673600	-1.25333200	-1.39089800
C	-1.00849100	-1.36278100	0.13687600
C	-1.00618700	1.36364800	0.13733300
C	-1.16450900	1.25500300	-1.39048700
C	-1.89775500	0.00155900	-1.86320400
H	-0.17091900	-1.28498200	-1.84051200
H	-1.69028600	-2.15567000	-1.71807700
H	-1.68640500	2.15839100	-1.71741200
H	-0.16864100	1.28497600	-1.84011600
H	-2.94054900	0.00244800	-1.53387500
H	-1.93519100	0.00177700	-2.95536700
N	-0.54699800	-0.00005600	0.69973500
O	0.11089800	-0.00072000	1.68816500
C	0.04329700	2.40330000	0.52802300
H	-0.23943300	3.35074900	0.06553400
H	0.09888700	2.55870600	1.60482700
H	1.02778900	2.12095800	0.15675400
C	-2.34490400	1.68240400	0.85046800
H	-2.24776600	1.60646800	1.93480200
H	-2.59112600	2.71828700	0.60991200
H	-3.17269300	1.05961600	0.52008100
C	-2.34770300	-1.67933500	0.85005000
H	-3.17425900	-1.05464300	0.52018400
H	-2.59605000	-2.71456300	0.60887100
H	-2.25022100	-1.60426000	1.93441200
C	0.03927400	-2.40434900	0.52696800
H	0.09521800	-2.55988000	1.60373700
H	-0.24548700	-3.35126300	0.06462100
H	1.02396200	-2.12364300	0.15498700
C	3.25544100	-0.00774900	0.26292000
C	4.74679000	0.00433500	-0.07640000
H	3.00818900	0.85999700	0.88238600
H	3.01860800	-0.88961900	0.86615500
H	5.02865300	-0.87303000	-0.66597800
H	5.01824100	0.89623400	-0.64885000
H	5.35135600	-0.00084600	0.83469400
N	2.34249600	-0.00260000	-0.90017600
H	2.54680300	-0.80580600	-1.49144500
H	2.54454900	0.80773700	-1.48244900

Figure 3-3 Optimized transition state geometries of **Transition state 1** as shown in Figure 3-1.

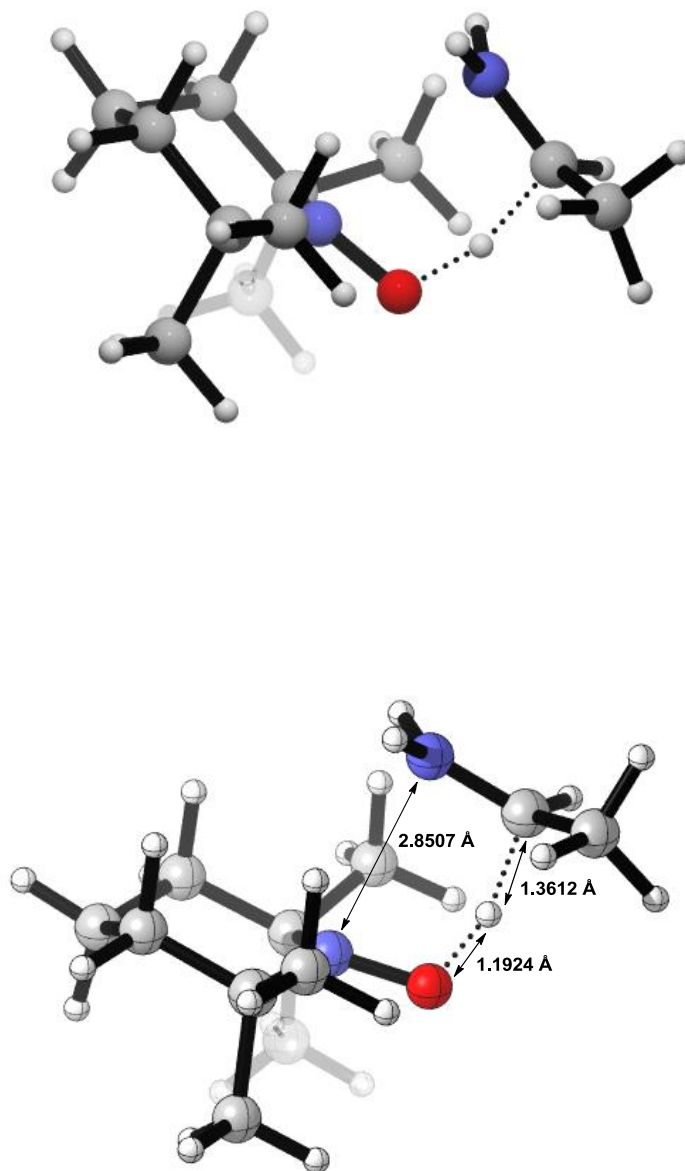


Table 3-4 Geometric Connectivity - Oxoammonium Cation and Ethyl Amine Transition State 1

freq rb3lyp/6-311+g(d)

Atom	X	Y	Z
1 1			
C	1.88918400	-1.03141100	1.10305300
C	1.04337200	-1.24735800	-0.16497900
C	0.56795100	1.39160600	-0.11238900
C	1.43897700	1.43298800	1.15511500
C	2.52181100	0.35592000	1.20445200
H	1.25758000	-1.19761900	1.98424000
H	2.65595000	-1.81058100	1.12777000
H	1.88084600	2.43085200	1.22238000
H	0.79050800	1.32586100	2.03313000
H	3.26333800	0.50777300	0.41477600
H	3.07141400	0.43593700	2.14587100
N	0.11966700	-0.04661700	-0.34467800
O	-0.78529600	-0.19504000	-1.24903400
C	-0.66195400	2.28765300	0.07027400
H	-0.32766300	3.31871900	0.19511600
H	-1.32295400	2.26250000	-0.79643600
H	-1.22623500	2.02855800	0.96762200
C	1.33270100	1.88932400	-1.35982800
H	0.73854000	1.74234800	-2.26323800
H	1.52338000	2.95918100	-1.25329300
H	2.29498000	1.40113400	-1.49622100
C	1.92032800	-1.40317900	-1.42735300
H	2.65528600	-0.60927100	-1.53677400
H	2.46685900	-2.34636000	-1.36357500
H	1.30460600	-1.43138800	-2.32780300
C	0.20136600	-2.52177400	-0.02139000
H	-0.43743200	-2.69560200	-0.88784900
H	0.87445700	-3.37628500	0.06196600
H	-0.40735700	-2.51984100	0.88524400
C	-2.82447600	-0.68009100	0.15207300
C	-3.93627500	0.26391500	-0.22413200
H	-1.85033300	-0.42063200	-0.76249100
H	-2.95300600	-1.73104600	-0.10792300
H	-4.83618000	0.01674800	0.35039300
H	-3.67896000	1.30502900	-0.01871200
H	-4.18321300	0.17186500	-1.28201000
N	-2.15470900	-0.48849400	1.31612900
H	-1.72484000	-1.25483500	1.80961200
H	-2.25981600	0.36748900	1.84094700

Figure 3-4 Optimized geometries of the **Pre-reaction complex** leading to **Transition state 2** as shown in Figure 3-1.

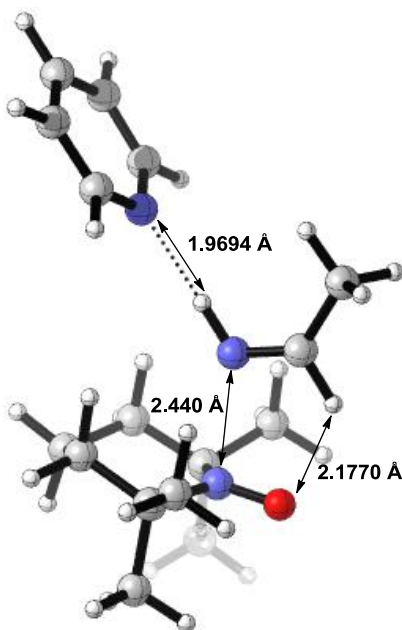
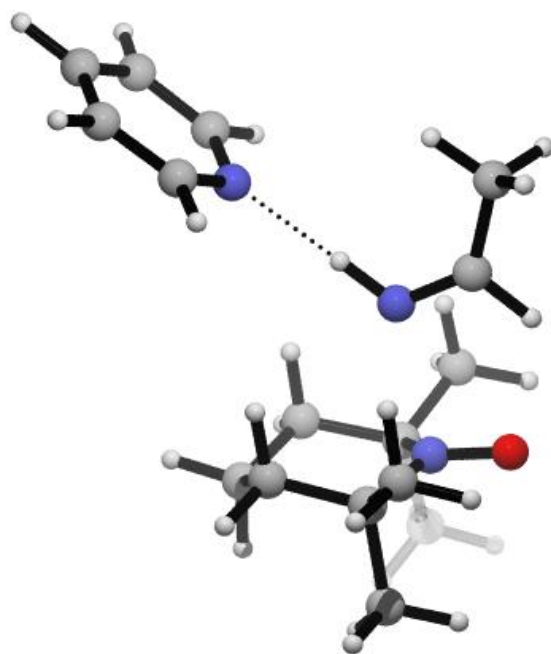


Table 3-5 Geometric Connectivity - Oxoammonium Cation, Pyridine, & Aldimine Initial Complex Step 2

opt rb3lyp/6-311+g(d)

Atom	X	Y	Z
1 1			
C	1.10866000	-1.51990300	-1.26268300
C	2.13167500	-0.38148700	-1.36491900
C	2.13124000	-0.38213300	1.36495000
C	1.10826100	-1.52050400	1.26185800
C	1.23386900	-2.37625700	-0.00059500
H	0.10460700	-1.09321400	-1.31428600
H	1.22997700	-2.13934700	-2.15627200
H	1.22931300	-2.14036700	2.15519200
H	0.10419000	-1.09384400	1.31334800
H	2.17137400	-2.94015300	-0.00058300
H	0.44017600	-3.12759800	-0.00089300
N	2.21084100	0.37209800	0.00019200
O	2.73221600	1.45476200	0.00053500
C	1.76494600	0.61794300	2.46119700
H	1.78037500	0.08821500	3.41563300
H	2.48153800	1.43674200	2.52631500
H	0.76736700	1.02497200	2.31637400
C	3.56346000	-0.90073300	1.64257900
H	4.30018500	-0.10090400	1.55413300
H	3.58328100	-1.25780600	2.67369400
H	3.86106200	-1.72978400	1.00645800
C	3.56398600	-0.89996400	-1.64233000
H	3.86142500	-1.72925200	-1.00644200
H	3.58411500	-1.25664400	-2.67357400
H	4.30067000	-0.10015400	-1.55336500
C	1.76573800	0.61907200	-2.46084900
H	2.48229400	1.43795400	-2.52530600
H	1.78158200	0.08978600	-3.41552300
H	0.76806900	1.02595700	-2.31624200
C	0.03270000	2.45736000	0.00030000
C	-1.05960300	3.48581800	0.00027800
H	1.06268100	2.85195500	0.00042500
H	-2.05049400	3.03249400	-0.00003800
H	-0.95600700	4.13353200	0.87664100
H	-0.95560200	4.13394000	-0.87573200
N	-0.08345800	1.20255300	0.00014100
H	-1.04859500	0.81568000	0.00004300
C	-3.51333400	-0.19362000	-1.14707300
C	-4.80693600	-0.70354100	-1.19817100
C	-5.46732400	-0.96369800	-0.00020500
C	-4.80710700	-0.70347800	1.19783900
C	-3.51349900	-0.19355700	1.14690000
N	-2.86710800	0.05958700	-0.00004500
H	-6.47707200	-1.35962100	-0.00026600
H	-2.97116300	0.02410500	-2.06332400
H	-5.28180700	-0.88833000	-2.15483300
H	-5.28211500	-0.88821400	2.15444500
H	-2.97146600	0.02422500	2.06321800

Figure 3-5 Optimized transition state geometries of **Transition state 2** as shown in Figure 3-1.



Table 3-6 Geometric Connectivity - Oxoammonium Cation, Pyridine, and Aldimine Transition State 2

Atom	X	Y	Z
1 1			
C	1.15996400	-1.84357700	-1.12667000
C	1.99718400	-0.55967700	-1.26395500
C	1.87144300	-0.35956000	1.39319100
C	1.02626800	-1.64388100	1.36463400
C	1.34858100	-2.57662500	0.19978300
H	0.10100700	-1.58566400	-1.24620100
H	1.41534900	-2.49757600	-1.96608800
H	1.15990600	-2.15626300	2.32218400
H	-0.03144400	-1.36113800	1.30865800
H	2.36334100	-2.97614100	0.28519500
H	0.68617600	-3.44687500	0.23425900
N	1.85324500	0.27374500	0.00569000
O	2.43398000	1.42687100	-0.05670300
C	1.28029600	0.62621600	2.40868300
H	1.39559000	0.20968000	3.41151600
H	1.80016500	1.58481600	2.39027200
H	0.21955800	0.80006000	2.23260200
C	3.33211100	-0.64240200	1.80809300
H	3.94103200	0.25662300	1.70205100
H	3.35655300	-0.94249700	2.85820400
H	3.79786200	-1.43920100	1.23203900
C	3.48920400	-0.87867500	-1.50395000
H	3.89131000	-1.60613900	-0.80109600
H	3.60976100	-1.29435000	-2.50710200
H	4.09156000	0.02870800	-1.44292100
C	1.49659900	0.25606300	-2.46235000
H	2.08632500	1.16177100	-2.60938300
H	1.59794400	-0.35124800	-3.36469200
H	0.44893700	0.53211300	-2.35519900
C	0.16119900	2.46454000	-0.21934000
C	-0.17875200	3.91999600	-0.33860700
H	1.45802700	2.27694000	-0.19680200
H	-1.25789900	4.08068600	-0.32027000
H	0.28777500	4.47952500	0.47509800
H	0.22870900	4.31225400	-1.27325000
N	-0.36427400	1.38686500	-0.14315000
H	-1.77225800	0.66975400	-0.03479100
C	-3.13054600	-0.35190400	-1.10546400
C	-4.36652000	-0.96848800	-1.19411800
C	-5.18876000	-0.99373600	-0.06771300
C	-4.75979300	-0.39322500	1.11610400
C	-3.51358500	0.20718200	1.14527100
N	-2.73799800	0.21896300	0.04485700
H	-6.15764600	-1.47814900	-0.11254800
H	-2.43746000	-0.28875900	-1.93575300
H	-4.67542100	-1.41986200	-2.12839300
H	-5.37908900	-0.39170500	2.00404300
H	-3.10367500	0.69718800	2.01865800

3.2 Development of a Metal-Free, Catalytic Oxidation of Primary Amines to Nitriles²³

General Considerations

All reactions were carried out in clean, dried glassware. The digital syringe pump was calibrated prior to use. Silica gel (40-63 μm particle size), used to separate impurities from the desired product, was purchased from Dynamic Adsorbents, Inc. NMR spectra (^1H , ^{13}C , ^{19}F) were recorded in deuterated chloroform on a Bruker DRX-400 400 MHz NMR spectrometer, and chemical shifts are reported in parts per million (ppm). ^1H and ^{13}C NMR spectra were referenced at $\delta = 7.26$ and 77.23 , respectively, for the residual ^1H resonance of the solvent and the center line of the ^{13}C adsorption for deuterated chloroform. Chemical shifts are reported relative to TMS at $\delta = 0.00$. ^{19}F NMR spectra were recorded in CDCl_3 , with fluorobenzene used as an internal standard ($\delta = -113.15$), and chemical shifts are reported relative to CCl_3F at $\delta = 0.00$. IR spectra were obtained on a Bruker ALPHA FT-IR spectrometer. All amines oxidized were known compounds and afforded nitrile products known to the literature, and whose ^1H and ^{13}C NMR spectra were in complete agreement with those reported. Melting points are not corrected, and refractive indices were corrected to 25°C using the following equation: $(\text{Refractive index at } T_1) - [(T_1 - 25)(0.00045)] = \text{Refractive index at } 25^\circ\text{C}$.

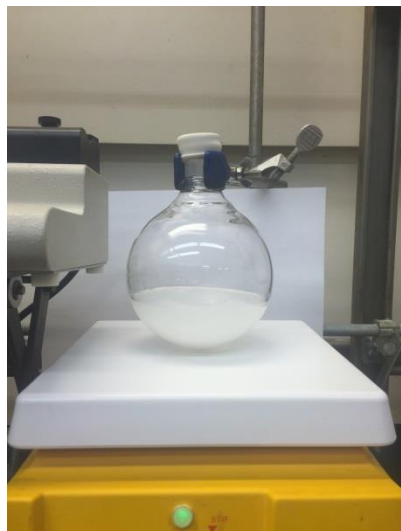
Reagents

Deuterated chloroform used as an NMR solvent was purchased from Cambridge Isotope Laboratories and stored over 4 Å molecular sieves. Fluorobenzene, thionyl chloride, and ammonium hydroxide were purchased from ACROS. Sodium sulfate, pyridine, dimethylformamide, dichloromethane, tetrahydrofuran, and diethyl ether (ACS reagent grade) were purchased from Sigma-Aldrich. Anhydrous dichloromethane was acquired through distillation from calcium hydride immediately preceding use. Anhydrous tetrahydrofuran was distilled immediately prior to use from a dark purple solution of sodium/benzophenone ketal. Pyridine was dried over calcium hydride and distilled just prior to use. Literature procedures were used to prepare cinnamylamine⁴ and 1-adamantylamine²⁴ with minor modifications as described. 4-acetamidoTEMPO (ACT, 2) was prepared in multimolar quantities from

the published procedure⁵, and recrystallized from ethyl acetate prior to use. Oxone, the terminal oxidant, was purchased from Alfa Aesar and has the empirical formula of $2\text{KHSO}_5 \cdot \text{KHSO}_4 \cdot \text{K}_2\text{SO}_4$. The commercially available aldehyde scavenger, Silabond® Amine, was purchased from Silicycle® Inc.

Colorimetric Description

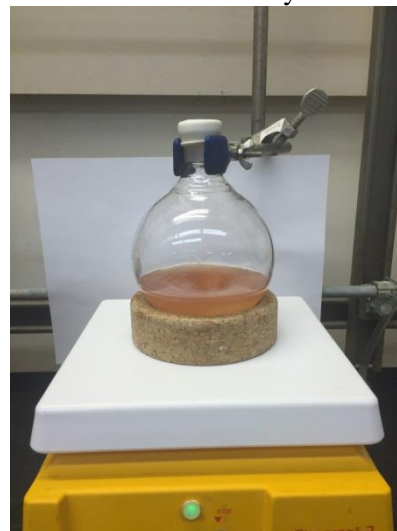
Oxone and pyridinium bromide
in CH_2Cl_2 upon mixing



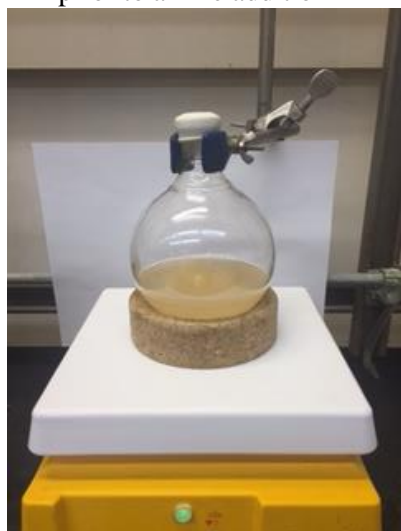
Oxone and pyridinium bromide
in CH_2Cl_2 after 15–20 minutes



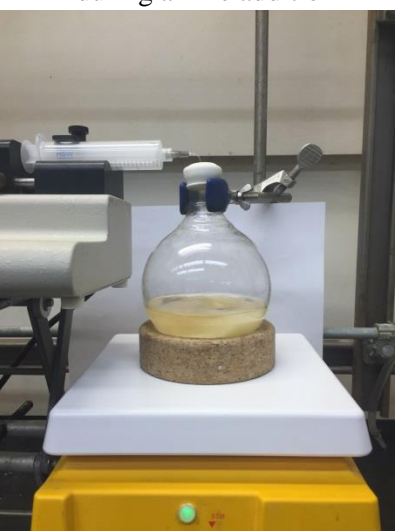
Oxone and pyridinium bromide
in CH_2Cl_2 after addition of
the ACT catalyst



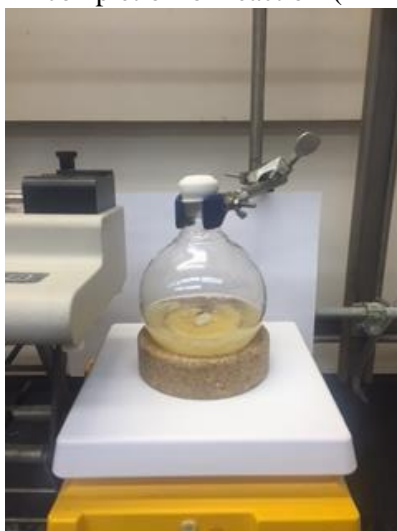
Oxone, pyridinium bromide,
ACT, and pyridine in CH_2Cl_2
prior to amine addition



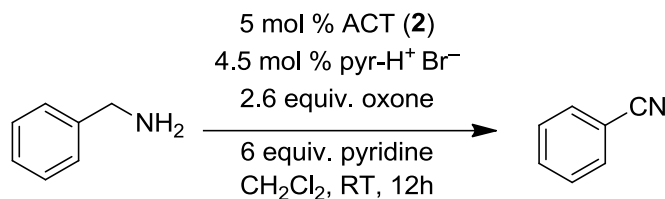
Oxone, pyridinium bromide,
ACT, and pyridine in CH_2Cl_2
during amine addition



Oxone, pyridinium bromide,
ACT, and pyridine in CH_2Cl_2 after
completion of reaction (12 h)

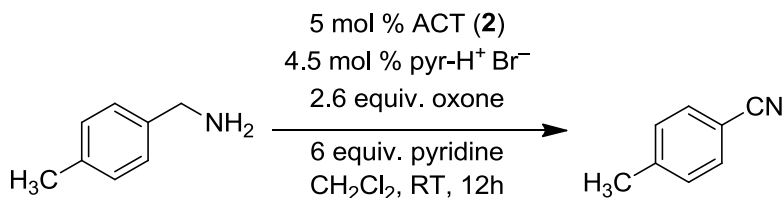


Representative Procedure for Oxidation of Primary Amines to Nitriles

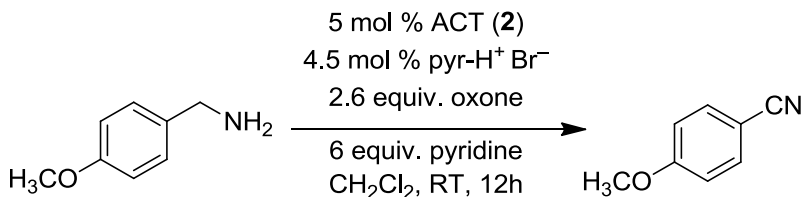


Benzonitrile²⁵ (Table 2-6, entry 1); To a clean and dry 250 mL round bottomed flask containing a magnetic stir bar was added 16.003 g (44.0 mmol, 4.4 equiv.) of oxone, 100 mL of dichloromethane and 72 mg (0.45 mmol, 0.045 equiv.) of pyridinium bromide. The mixture was stirred for 15 minutes, resulting in a faint yellow solution. To the reaction mixture was added 4.773 g (60.3 mmol, 6.0 equiv.) of pyridine, followed by 107 mg (0.5 mmol, 0.05 equiv.) of ACT. The heterogeneous mixture was stirred for an additional 15 minutes, at which point a solution of 1.081 g benzylamine (10.0 mmol, 1.0 equiv.) in 20 mL of dichloromethane (0.5 M) was added by syringe pump at a rate of 10 mL/h and the reaction mixture was allowed to continue stirring at room temperature for 12 h. The reaction mixture was then filtered through a short plug of silica gel (50 g). The residual solid on top of the silica plug was then rinsed with an additional 100 mL of dichloromethane. The majority of solvent was removed on a rotary evaporator operating at room temperature. With an approximate total volume of 10 mL remaining, 50–100 mg of SiliaBond[®] Amine was added and stirred for 3–4 h. The mixture was then passed through a small pipette containing 100 mg of silica gel, and the filtrate was concentrated under reduced pressure, yielding 944 mg (92%) of the title compound as a clear, light yellow oil: $n_D^{25} = 1.5259$ (lit. 1.5257); ¹H NMR (400 MHz, CDCl₃) δ 7.56–7.62 (m, 3H), 7.44 (t, $J = 7.73$ Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 132.8, 132.1, 129.2, 118.9, 112.4; FT-IR (cm⁻¹, neat, ATR) 3065 (s), 2228 (m), 1490 (m), 1447 (m), 755 (s), 685 (s), 546 (s); GC-MS (EI) 103 ([M]⁺, 100%), 76 (36%), 50 (19%).

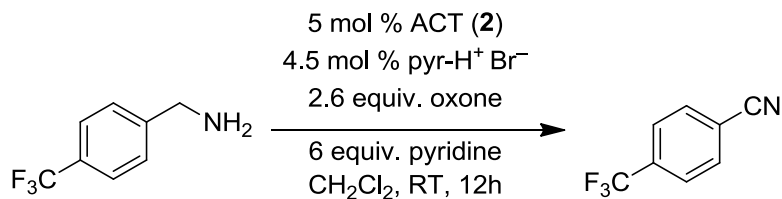
Preparation and Characterization of Nitriles



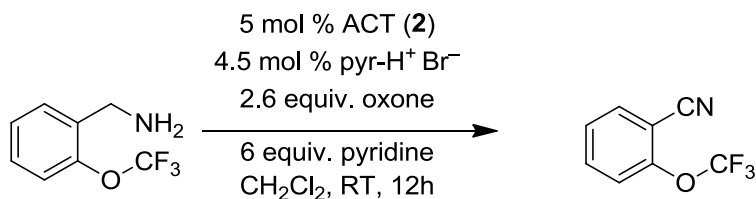
4-Methylbenzonitrile⁸ (Table 2-6, entry 2); Was prepared using the representative procedure from 4-methylbenzylamine (1.234 g, 10.2 mmol) to afford 1.066 g (89%) of the title product as a white solid: mp 27.1–27.7 °C (lit. 26 – 28 °C); ¹H NMR (400 MHz, CDCl₃) δ 7.57 (d, *J* = 8.11 Hz, 2H), 7.30 (d, *J* = 8.11 Hz, 2H), 2.45 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 143.9, 132.3, 130.0, 119.4, 109.6, 22.1; FT–IR (cm^{–1}, neat, ATR) 3037 (vw), 2924 (vw), 2225 (s), 1605 (m), 1509 (m), 1200 (m), 814 (s), 544 (s), 438 (m); GC-MS (EI) 117 ([M]⁺, 100%), 90 (51%), 63 (19%), 51 (10%), 39 (14%).



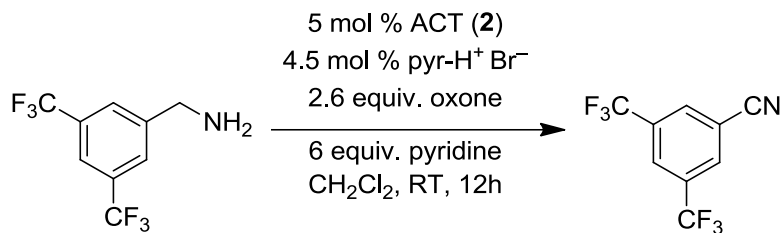
4-Methoxybenzonitrile²⁶ (Table 2-6, entry 3); Was prepared using the representative procedure from 4-methoxybenzylamine (1.399 g, 10.2 mmol) to yield 1.172 g (86%) of the title compound as a white solid: mp 58.5 – 58.8 °C (lit. 58 – 59 °C); ¹H NMR (400 MHz, CDCl₃) δ 7.58 (d, *J* = 8.76 Hz, 2H), 6.95 (d, *J* = 8.76 Hz, 2H), 3.85 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 163.0, 134.2, 119.4, 114.9, 104.2, 55.7; FT–IR (cm^{–1}, neat, ATR) 2941 (w, br), 2843 (w), 2216 (s), 1603 (s), 1506 (s), 1255 (s), 1173 (m), 1021 (s), 826 (s), 681 (m) 544 (s); GC-MS (EI) 133 ([M]⁺, 100%), 103 (35%), 90 (52%), 63 (20%), 50 (10%), 39 (11%).



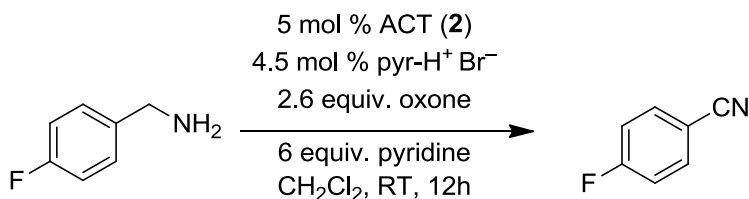
4-(Trifluoromethyl)benzonitrile¹⁴ (Table 2-6, entry 4); Was prepared using the representative procedure from 4-(trifluoromethyl)benzylamine (1.752 g, 10.0 mmol) to afford 1.463 g (86%) of the title compound as a white solid: mp 37.1–37.8 °C (lit. 36–37 °C); ¹H NMR (400 MHz, CDCl₃) δ 7.81 (d, *J* = 8.36 Hz, 2H), 7.76 (d, *J* = 8.36 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 134.8 (q, *J*_{C,F} = 33.4), 132.9, 126.4 (q, *J*_{C,F} = 3.8), 123.3 (q, *J*_{C,F} = 273.2 Hz), 117.6, 116.3 (q, *J*_{C,F} = 1.4 Hz); ¹⁹F NMR (376 MHz, CDCl₃) δ –63.6; FT-IR (cm⁻¹, neat, ATR) 3059 (w), 2236 (m), 1414 (w), 1355 (s), 1160 (m), 1132 (s), 1106 (s), 1058 (s), 1017 (m), 861 (m), 837 (s), 730 (w), 596 (m), 546 (m), 537 (m); GC-MS (EI) 171 ([M]⁺, 100%), 152 (52%), 121 (62%), 102 (12%), 75 (21%).



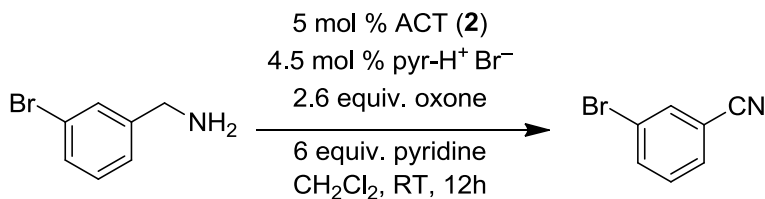
2-(Trifluoromethoxy)benzonitrile²⁷ (Table 2-6, entry 5); Was prepared using the representative procedure from 2-(trifluoromethoxy)benzylamine (1.919 g, 10.0 mmol) to afford 1.654 g (88%) of the title product as a clear yellow oil: *n*_D²⁵ = 1.4519 (lit. 1.4518); ¹H NMR (400 MHz, CDCl₃) δ 7.71 (dd, *J* = 7.70 Hz, *J* = 1.30 Hz, 1H), 7.67 (td, *J* = 8.06 Hz, *J* = 1.53 Hz, 1H), 7.39 – 7.44 (m, 2H) ¹³C NMR (100 MHz, CDCl₃) δ 150.1 (q, *J*_{C,F} = 1.8 Hz), 134.7, 134.2, 127.5, 121.3 (q, *J*_{C,F} = 1.5 Hz), 120.4 (q, *J*_{C,F} = 260.4 Hz), 114.4, 107.3; ¹⁹F NMR (376 MHz, CDCl₃) δ –57.8; FT-IR (cm⁻¹, neat, ATR) 2238 (m), 1604 (m), 1491 (m), 1452 (m), 1253 (m), 1202 (s), 1162 (s, br), 1102 (m), 770 (m), 753 (m), 630 (m); GC-MS (EI) 187 ([M]⁺, 82%), 159 (51%), 90 (34%), 69 (100%), 63 (19%), 39 (16%).



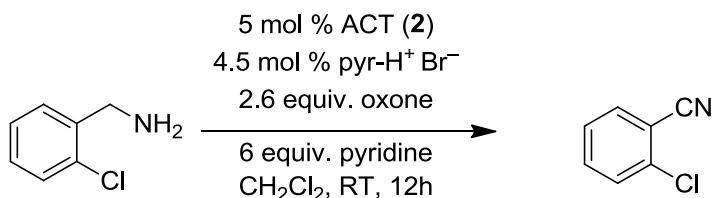
3,5-Bis-(trifluoromethyl)benzonitrile¹⁷ (Table 2-6, entry 6); Was prepared using the representative procedure from 3,5-bis-(trifluoromethyl)benzylamine (2.438 g, 10.0 mmol) to afford 2.071 g (87%) of the title product as a clear, yellow oil: $n_D^{25} = 1.4204$ (not previously reported in the lit.); ¹H NMR (400 MHz, CDCl₃) δ 8.13 (s, 2H), 8.12 (s, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 133.3 (q, $J_{C,F} = 34.8$ Hz), 132.5 (q, $J_{C,F} = 3.2$ Hz), 126.7 (sept, $J_{C,F} = 3.4$ Hz), 122.4 (q, $J_{C,F} = 273.1$ Hz), 116.1, 115.2; ¹⁹F NMR (376 MHz, CDCl₃) δ -63.4; FT-IR (cm⁻¹, neat, ATR) 3092 (vw), 2241 (w), 1620 (w), 1459 (w), 1376 (s), 1276 (s), 1130 (s), 904 (m), 850 (m), 683 (m), 628 (m); GC-MS (EI) 239 ([M]⁺, 100%), 220 (80%), 189 (31%), 170 (87%), 150 (11%), 139 (10%), 99 (12%), 75 (17%), 69 (26%).



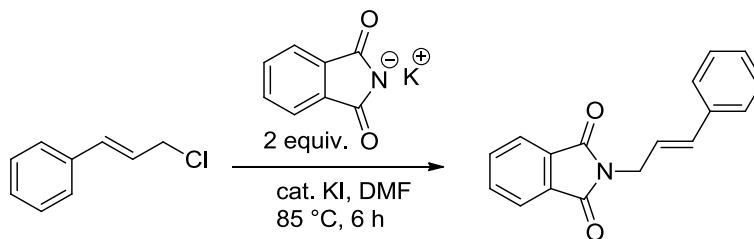
4-Fluorobenzonitrile²⁸ (Table 2-6, entry 7); Was prepared using the representative procedure from 4-fluorobenzylamine (1.259 g, 10.1 mmol). **NOTE:** *The title compound readily sublimates under gentle warming at reduced pressure (≈ 30 °C at 20 mm Hg), thus careful removal of the solvent at a temperature no greater than 25 °C is necessary to limit loss of product.* Careful work-up yields 1.058 g (87%) of the title compound as a white solid: mp 34.3–35.2 °C (lit. 34–35 °C); ¹H NMR (400 MHz, CDCl₃) δ 7.68 (dd, $J = 8.72$ Hz, $J = 5.16$ Hz, 2H), 7.18 (t, $J = 8.52$ Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 165.3 (d, $J_{C,F} = 256.5$ Hz), 134.9 (d, $J_{C,F} = 9.3$ Hz), 118.2, 117.1 (d, $J_{C,F} = 22.7$ Hz), 108.8 (d, $J_{C,F} = 3.2$ Hz); ¹⁹F NMR (376 MHz, CDCl₃) δ -102.5; FT-IR (cm⁻¹, neat, ATR) 3113 (w), 3071 (w), 2233 (m), 1911 (w), 1604 (s), 1508 (s), 1408 (m), 1239 (s), 1164 (s), 831 (s), 684 (s), 539 (s); GC-MS (EI) 121 ([M]⁺, 100%), 94 (32%), 50 (12%).



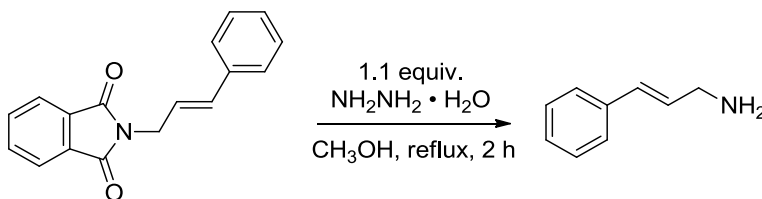
3-Bromobenzonitrile²⁹ (Table 2-6, entry 8); Was prepared using the representative procedure from 3-bromobenzylamine (1.859 g, 10.0 mmol) to afford 1.562 g (86%) of the title compound as an off-white crystalline solid: mp 39.7–40.2 °C (lit. 39–40 °C); ¹H NMR (400 MHz, CDCl₃) δ 7.79 (t, *J* = 1.56 Hz, 1H), 7.74 (ddd, *J* = 8.15 Hz, *J* = 1.84 Hz, *J* = 1.05 Hz, 1H), 7.60 (dt, *J* = 7.76 Hz, *J* = 1.13 Hz, 1H), 7.36 (t, *J* = 7.94 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 136.3, 134.9, 130.9, 130.8, 123.1, 117.5, 114.4; FT-IR (cm⁻¹, neat, ATR) 3091 (w), 3080 (w), 2924 (w), 2229 (m), 1557 (m), 1464 (m), 1407 (m), 1226 (m), 1188 (m), 1075 (m), 893 (m), 782 (s), 674 (s), 438 (s); GC-MS (EI) 183 ([M]⁺, ⁸¹Br, 92%), 181 ([M]⁺, ⁷⁹Br, 93%), 102 (100%), 75 (37%), 51 (29%).



2-Chlorobenzonitrile¹⁸ (Table 2-6, entry 9); Was prepared using the representative procedure from 2-chlorobenzonitrile (1.403 g, 9.9 mmol) to yield 1.330 g (98%) of the title compound as a white powder: mp 43.2–43.9 °C (lit. 43–45 °C); ¹H NMR (400 MHz, CDCl₃) δ 7.67 (dd, *J* = 7.78 Hz, *J* = 1.30 Hz, 1H), 7.49 – 7.58 (m, 2H), 7.38 (ddd, *J* = 7.73 Hz, *J* = 7.06 Hz, *J* = 1.65 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 137.1, 134.2, 134.0, 130.2, 127.3, 116.1, 113.6; FT-IR (cm⁻¹, neat, ATR) 3066 (vw), 2229 (m), 1590 (m), 1471 (m), 1437 (m), 1055 (w), 757 (s), 676 (m), 458 (m); GC-MS (EI) 139 ([M]⁺, ³⁷Cl, 31%), 137 ([M]⁺, ³⁵Cl, 100%), 102 (27%), 75 (20%), 50 (15%).

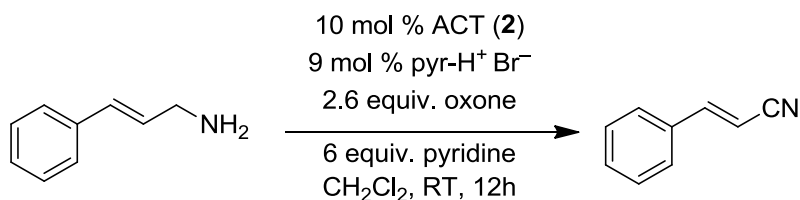


(E)-N-cinnamylphthalimide³⁰; Was prepared following the procedure described by Moody et. al.⁴ To a dry 100 mL round bottomed flask containing 75 mL of dimethylformamide was added 15.440 g (101.0 mmol, 1.0 equiv.) of (E)-cinnamyl chloride, 37.481 g (202.0 mmol, 2.0 equiv.) of potassium phthalimide and a catalytic amount of potassium iodide. The resulting mixture was then stirred for 6 h at 85 °C. The mixture was diluted with 350 mL of deionized water and extracted four times with 100 mL dichloromethane. The combined organic layers were washed with 80 mL of a 0.2 M aqueous sodium hydroxide solution five times, followed by 100 mL of deionized water, and 100 mL of brine. The organic layer was dried over sodium sulfate and solvent was removed under reduced pressure to afford 24.567 g of a crude yellow solid. Recrystallization from a warm solution of dichloromethane/pentane afforded 20.563 g (77 %) of the title compound as a white solid: mp 154.5–155 °C (lit. 150.5–151.2 °C); ¹H NMR (400 MHz, CDCl₃) δ 7.86 (dd, *J* = 5.41 Hz, *J* = 3.08 Hz, 2H), 7.71 (dd, *J* = 5.45 Hz, *J* = 3.03 Hz, 2H), 7.34 – 7.36 (m, 2H), 7.26 – 7.30 (m, 2H), 7.20 – 7.23 (m, 1H), 6.66 (d, *J* = 15.83 Hz, 1H), 6.26 (dt, *J* = 15.82 Hz, *J* = 6.48 Hz, 1H), 4.45 (dd, *J* = 6.48 Hz, *J* = 1.04 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 168.1, 136.4, 134.1, 134.0, 132.4, 128.7, 128.1, 126.7, 123.5, 122.9, 39.8.



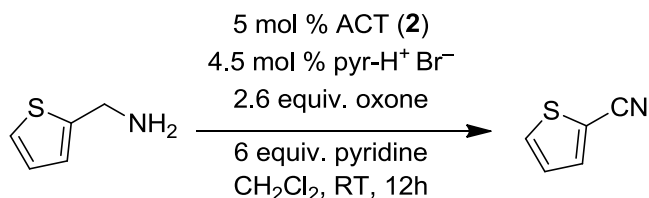
(E)-cinnamylamine³¹; Was prepared following the procedure outlined by Moody et. al.⁴ To a dry 500 mL round bottomed flask was added 350 mL of methanol, 20.563 g (78.1 mmol, 1.0 equiv.) of (E)-N-cinnamylphthalimide and 2.753 g (85.8 mmol, 1.1 equiv.) of hydrazine monohydrate. The resulting mixture was then refluxed for 2 h. After cooling to room temperature, the reaction mixture was acidified

with 50 mL (40.0 mmol, 0.5 equiv.) of conc. hydrochloric acid, and then refluxed for an additional 30 minutes. After cooling to room temperature, the reaction mixture was filtered through a Büchner funnel and the precipitate was washed with cold methanol. The filtrate was then concentrated and the residue was partially dissolved in ethanol. The mixture was then filtered and the filtrate was concentrated. The residue was dissolved in water, basified to pH 12 with solid potassium hydroxide pellets, and extracted three times with 50 mL of diethyl ether. The organic layers were combined, dried over sodium sulfate and the solvent was removed under reduced pressure to afford a crude yellow oil. Distillation (Kugelrohr, bath temperature: 155 °C at 10 mm) afforded 7.197 g (69%) of the title compound as a clear, colorless oil: $n_D^{25} = 1.5810$ (lit. 1.5857); ^1H NMR (400 MHz, CDCl_3) δ 7.21 – 7.41 (m, 5H), 6.52 (d, $J = 15.89$ Hz, 1H), 6.33 (dt, $J = 15.87$ Hz, $J = 5.77$ Hz, 1H), 3.48 (dd, $J = 5.77$ Hz, $J = 1.26$ Hz, 2H), 1.29 (br s, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 137.3, 131.4, 129.4, 128.6, 127.3, 126.2, 44.3.

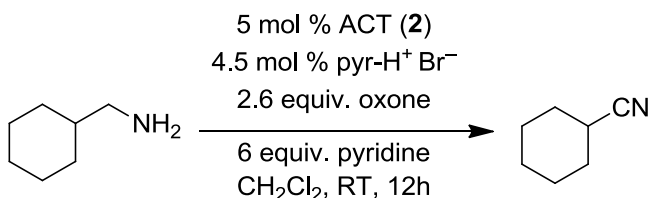


(E)-cinnamionitrile³² (Table 2-6, entry 10); Was prepared according to the representative procedure from (E)-cinnamyl amine (1.346 g, 10.1 mmol) to afford 935 mg (72%) of the title compound as a clear oil: $n_D^{25} = 1.5919$ (lit. 1.6001). A modified procedure, in which the amounts of pyridinium bromide and ACT were increased to 9 mol % and 10 mol %, respectively, resulted in a greater yield of the isolated nitrile. The revised procedure is as follows: the title compound was prepared from cinnamyl amine (1.319 g, 9.9 mmol) according to the representative procedure, except 147 mg (0.9 mmol, 9 mol %) of pyridinium bromide and 213 mg (0.1 mmol, 10 mol %) of ACT were employed, yielding 1.140 g (89%) of the title compound as a clear oil: $n_D^{25} = 1.5959$ (lit. 1.6001); ^1H NMR (400 MHz, CDCl_3) δ 7.38 – 7.46 (m, 5H), 7.38 (d, $J = 16.70$, 1H), 5.87 (d, $J = 16.70$ Hz, 1H); ^{13}C NMR (100 MHz, CDCl_3) δ 150.7, 133.6, 131.3, 129.2, 127.5, 118.3, 96.4; FT-IR (cm^{-1} , neat, ATR) 3054 (w), 2216 (s), 1617 (s), 1577 (m),

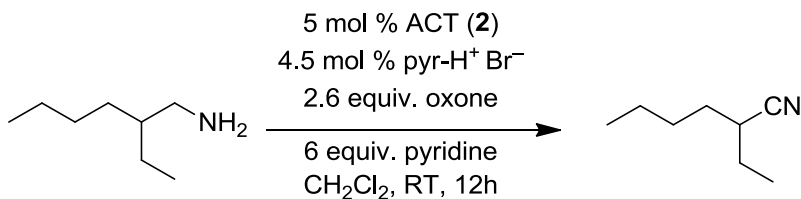
1448 (m), 1207 (m), 964 (s), 746 (s), 687 (s), 436 (m); GC-MS (EI) 129 ($[M]^+$, 100 %), 102 (38%), 76 (14%), 63 (10%), 51 (24%).



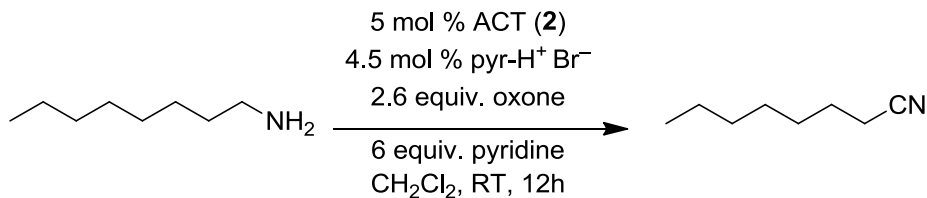
2-Cyanothiophene³³ (Table 2-6, entry 11); Was prepared using the representative procedure from 2-thiophenemethylamine (1.132 g, 10.0 mmol) to afford 984 mg (90%) of the title product as a yellow oil: $n_D^{25} = 1.5589$ (lit. 1.562); ^1H NMR (400 MHz, CDCl_3) δ 7.60 – 7.62 (m, 2H), 7.11 – 7.13 (m, 1H); ^{13}C NMR (100 MHz, CDCl_3) δ 137.5, 132.7, 127.8, 114.3, 109.9; FT-IR (cm^{-1} , neat, ATR) 3098 (m), 2220 (s), 1413 (s), 1231 (s), 1156 (m), 1040 (m), 854 (s), 713 (vs), 566 (m), 524 (m); GC-MS (EI) 109 ($[M]^+$, 100%), 64 (11%), 58 (35%), 45 (45%).



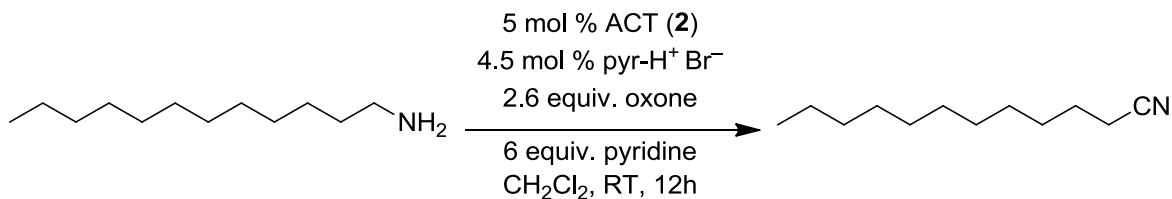
Cyclohexanecarbonitrile³⁴ (Table 2-6, entry 12); Was prepared using the representative procedure from cyclohexylmethylamine (1.132 g, 10.0 mmol) to yield 1.056 g (97%) of the title compound as a clear, colorless oil: $n_D^{25} = 1.4524$ (lit. 1.453); ^1H NMR (400 MHz, CDCl_3) δ 2.59 (tt, $J = 8.03$ Hz, $J = 3.97$ Hz, 1H) 1.73 – 1.84 (m, 2H), 1.62 – 1.72 (m, 4H), 1.46 – 1.51 (m, 4H); ^{13}C NMR (100 MHz, CDCl_3) δ 122.7, 29.6, 28.1, 25.3, 24.1; FT-IR (cm^{-1} , neat, ATR) 2934 (s), 2859 (m), 2241 (m), 1451 (s), 915 (m), 731 (s); GC-MS (EI) 109 ($[M]^+$, 15%), 108 ($[M-1]^+$, 21%), 94 (30%), 81 (23%), 67 (34%), 56 (100%), 41 (90%).



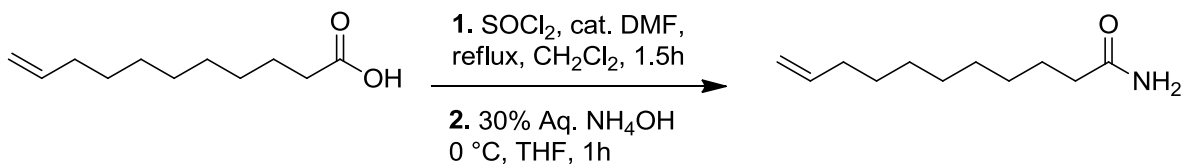
2-Ethylhexanenitrile³⁵ (Table 2-6, entry 13); Was prepared using the representative procedure from 2-ethyl-1-hexylamine (1.319 g, 10.2 mmol) to afford 1.172 g (92%) of the title product as a clear, yellow oil: $n_D^{25} = 1.4193$ (lit. 1.4145); ^1H NMR (400 MHz, CDCl_3) δ 2.38 – 2.45 (m, 1H), 1.44 – 1.62 (m, 8H), 1.03 (t, $J = 7.44$ Hz, 3H), 0.88 (t, $J = 7.20$ Hz, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 122.3, 33.3, 31.7, 29.3, 25.6, 22.3, 13.8, 11.6; FT-IR (cm^{-1} , neat, ATR) 2962 (s), 2934 (s), 2863 (m), 2237 (m), 1461 (s), 1383 (m), 730 (w); GC-MS (EI) 125 ($[\text{M}]^+$ 0.6%), 124 ($[\text{M}-1]^+$, 1.0%), 97 (46%), 69 (77%), 54 (100%), 41 (69%).



Caprylonitrile³⁶ (Table 2-6, entry 14); Was prepared using the representative procedure from octylamine (1.292 g, 10.0 mmol) to yield 1.157 g (92%) of the title compound as a clear, colorless oil: $n_D^{25} = 1.4225$ (lit. 1.4163); ^1H NMR (400 MHz, CDCl_3) δ 2.29 (t, $J = 7.14$ Hz, 2H), 1.61 (quint, $J = 7.34$ Hz, 2H), 1.40 (quint, $J = 7.15$ Hz, 2H), 1.19 – 1.33 (m, 6H), 0.85 (t, $J = 6.67$ Hz, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 119.9, 31.5, 28.6, 28.4, 25.4, 22.5, 17.1, 14.0; FT-IR (cm^{-1} , neat, ATR) 2956 (m), 2928 (s), 2858 (m), 2248 (w), 1461 (m), 1427 (w), 1378 (vw), 913 (m), 732 (s), 648 (vw); GC-MS (EI) 125 ($[\text{M}]^+$ 0.4 %), 124 ($[\text{M}-1]^+$, 2.7 %), 110 (11 %), 96 (47 %), 82 (100 %), 69 (40 %), 54 (49 %), 41 (98 %).

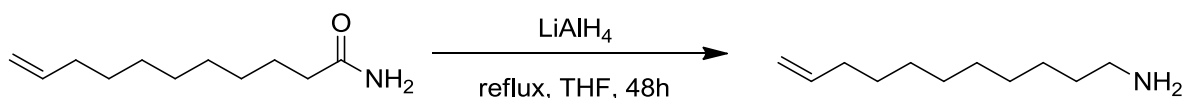


Lauronitrile³⁶ (Table 2-6, entry 15); Was prepared using the representative procedure from dodecylamine (1.854 g, 10.0 mmol) to yield 1.779 g (98%) of the title product as a clear, colorless oil: $n_D^{25} = 1.4374$ (lit. 1.4396); ¹H NMR (400 MHz, CDCl₃) δ 2.30 (t, $J = 7.15$ Hz, 2H), 1.63 (quint, $J = 7.38$ Hz, 2H), 1.42 (quint, $J = 7.25$ Hz, 2H), 1.33 – 1.20 (m, 14 H), 0.86 (t, $J = 6.84$ Hz, 3 H); ¹³C NMR (100 MHz, CDCl₃) δ 119.9, 32.0, 29.7, 29.6, 29.4, 28.9, 28.8, 25.5, 22.8, 17.2, 14.2; FT-IR (cm⁻¹, neat, ATR) 2923 (s), 2854 (m), 2246 (w), 1465 (m), 721 (m); GC-MS (EI) 182 ([M+1]⁺, 7%), 181 ([M]⁺, 0.6%), 180 ([M-1]⁺, 3%), 138 (24%), 124 (36%), 110 (59%), 97 (85%), 82 (56%), 69 (42%), 57 (62%), 41 (100%).

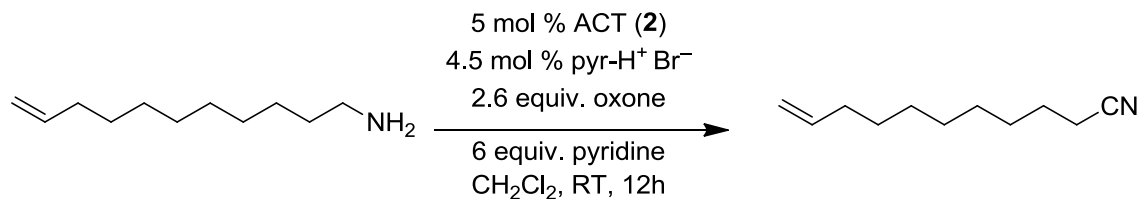


10-Undecenecarboxamide³⁷; Was prepared following the procedure described by Farcasiu et al.²⁴ To a dry 100 mL round bottomed flask containing a magnetic stir bar was added 18.458 g (100.2 mmol, 1.0 equiv) of 10-undecenoic acid, 40 mL of dichloromethane, and a catalytic amount of dimethylformamide. Following the immediate addition of 13.639 g (114.6 mmol, 1.1 equiv) of thionyl chloride, the flask was fitted with a Friedrich condenser equipped with an acid trap (1 M solution of sodium hydroxide) and refluxed until the evolution of hydrogen chloride gas ceased (~1.5 h). The solvent and excess thionyl chloride were then removed under reduced pressure. The crude acid chloride was dissolved in 30 mL of anhydrous tetrahydrofuran and slowly added to a stirred solution of 30 wt% aqueous ammonium hydroxide (150 mL) cooled to 0 °C. After 1 h of stirring, the mixture was filtered through a Büchner funnel and the solid dried under reduced pressure to yield 10.564 g (96%) of the title product as a powdery white solid; ¹H NMR (400 MHz, CDCl₃) δ 5.79 (ddt, $J = 17.03$ Hz, $J = 10.27$ Hz, $J = 6.71$ Hz, 1H), 4.98 (ddt, $J = 17.14$ Hz, $J = 1.82$ Hz, $J = 1.58$ Hz, 1H), 4.92 (ddt, $J = 10.15$ Hz, $J = 1.82$ Hz, $J =$

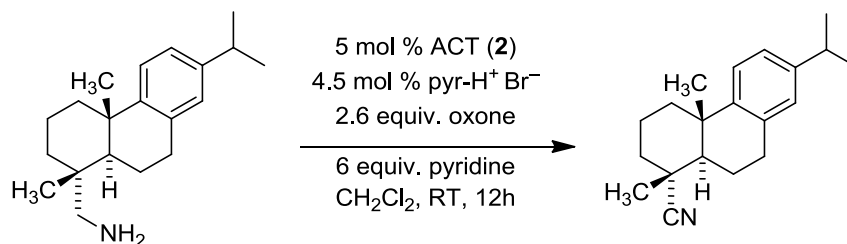
0.99 Hz, 1H), 2.87 (t, $J = 7.34$ Hz, 2H), 2.03 (q, $J = 7.04$ Hz, 2H), 1.70 (quint, $J = 7.29$ Hz, 2H), 1.21 – 1.46 (m, 10H); ^{13}C NMR (100 MHz, CDCl_3) δ 173.8, 139.2, 114.3, 47.2, 33.9, 29.3, 29.2, 29.1, 29.0, 28.5, 25.2.



10-Undeceneamine³⁸; Was prepared using the procedure described by Farcasiu et al.²⁴ To a dry 500 mL round bottomed flask containing a magnetic stir bar was added 4.300 g (113.3 mmol, 2.0 equiv) of lithium aluminum hydride and 200 mL of anhydrous tetrahydrofuran. Next, 10.564 g (57.6 mmol, 1.0 equiv) of 10-undecenecarboxamide was dissolved in 200 mL of anhydrous tetrahydrofuran and slowly added through a condenser to the lithium aluminum hydride slurry at a rate that maintained a gentle reflux of the reaction mixture. The slurry was then refluxed by way of a constant temperature oil bath for 2 days at 65–70 °C under a nitrogen atmosphere. The reaction mixture was then cooled to room temperature and carefully quenched with 11 mL of water, 22 mL of aqueous sodium hydroxide (1 M) and an additional 11 mL of water. The mixture was filtered through a Büchner funnel and the filtrate was collected. The caked white solid was then continuously extracted overnight with diethyl ether 100 mL in a Soxhlet extractor. The organic layers (filtrate & extract) were combined and washed with 100 mL of brine, dried over sodium sulfate, and upon removal of the solvent under reduced pressure afforded 8.181 g (84%) of the title compound as a clear, colorless oil; ^1H NMR (400 MHz, CDCl_3) δ 5.76 (ddt, $J = 17.03$ Hz, $J = 10.25$ Hz, $J = 6.74$ Hz, 1H), 4.94 (ddt, $J = 17.13$ Hz, $J = 1.68$ Hz, $J = 1.67$ Hz, 1H), 4.87 (dd, $J = 10.20$ Hz, $J = 0.88$ Hz, 1H), 2.62 (t, $J = 6.98$ Hz, 2H), 1.99 (q, $J = 7.06$ Hz, 2H), 1.16 – 1.45 (m, 14H), 1.04 (s, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 139.3, 114.2, 42.4, 34.1, 33.9, 29.7, 29.6, 29.6, 29.2, 29.1, 27.0.

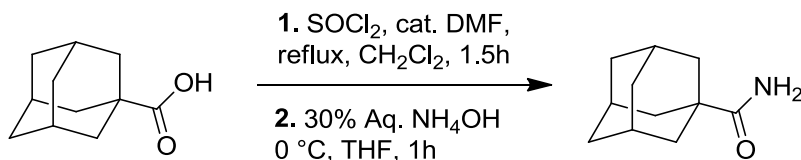


10-Undecenitrile³⁹ (Table 2-6, entry 16); Was prepared using the representative procedure from 10-undeceneamine (1.472 g, 8.7 mmol) to afford 825 mg (58%) of the title compound as a colorless oil; $n_D^{25}=1.4452$ (lit. 1.4464); ^1H NMR (400 MHz, CDCl_3) δ 5.80 (ddt, $J = 17.04$ Hz, $J = 10.26$ Hz, $J = 6.72$ Hz, 1H), 4.99 (ddt, $J = 17.13$ Hz, $J = 1.84$ Hz, $J = 1.58$ Hz, 1H), 4.93 (ddt, $J = 10.17$ Hz, $J = 1.88$ Hz, $J = 0.94$ Hz, 1H), 2.33 (t, $J = 7.14$ Hz, 2H), 2.04 (q, $J = 7.03$ Hz, 2H), 1.65 (quint, $J = 7.39$ Hz, 2H), 1.23 – 1.50 (m, 10H); ^{13}C NMR (100 MHz, CDCl_3) δ 139.3, 120.0, 114.4, 33.9, 29.3, 29.1, 29.0, 28.9, 28.8, 25.6, 17.3; FT-IR (cm^{-1} , neat, ATR) 3076 (w), 2925 (s), 2855 (m), 2246 (m), 1640 (m), 1462 (m), 993 (m), 908 (s), 733 (m), 633 (w); GC-MS (EI) 165 ($[\text{M}]^+$, 0.5%), 164 ($[\text{M}-1]^+$, 3.4%), 136 (51%), 122 (72%), 108 (19%), 94 (36%), 82 (28%), 69 (43%), 55 (100%), 41 (90%).

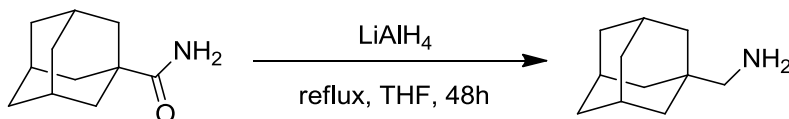


(+)-Dehydroabietyl nitrile⁴⁰ (Table 2-6, entry 17); Was prepared using the representative procedure from (+)-dehydroabietylamine (2.858 g, 10.0 mmol) to afford 2.474 g (88%) of the title compound as a white solid: mp 83.8–84.2 °C (lit. 84–85 °C); $[\alpha]_D^{21} = +59.6^\circ$ ($c = 0.4$ g/mL in ethanol) (lit. $[\alpha]_D^{20} = +61.8$ ($c = 0.4$ g/mL in ethanol)); ^1H NMR (400 MHz, CDCl_3) δ 7.17 (d, $J = 8.16$ Hz, 1H), 7.04 (d, $J = 8.16$ Hz, 1H), 6.95 (s, 1H), 2.95 – 3.10 (m, 2H), 2.86 (quint, $J = 6.90$ Hz, 1H), 2.34 (d, $J = 6.54$ Hz, 1H), 1.86 – 2.16 (m, 5H), 1.73 – 1.82 (m, 2H), 1.47 – 1.56 (m, 1H), 1.45 (s, 3H), 1.26 (d, $J = 6.89$ Hz, 6H), 1.22 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 146.3, 145.6, 134.3, 127.2, 126.7, 124.3, 124.2, 47.0, 37.7, 37.6, 37.5, 37.4, 33.6, 30.0, 25.3, 24.1, 24.1, 21.8, 19.0, 17.9; FT-IR (cm^{-1} , neat, ATR) 3009 (w), 2957 (s),

2929 (s), 2866 (m), 2226 (m), 1496 (m), 1458 (m), 1448 (m), 1443 (m), 1420 (m), 1382 (m), 1362 (m), 1011 (m), 907 (w), 889 (m), 859 (w), 817 (s), 751 (w), 708 (w), 632 (w), 609 (m), 478 (w), 432 (w); GC-MS (EI) 281 ($[M]^+$, 26%) 266 (100%) 224 (10%) 197 (11%) 141 (12%) 128 (14%) 117 (11%) 70 (15%) 43 (17%).

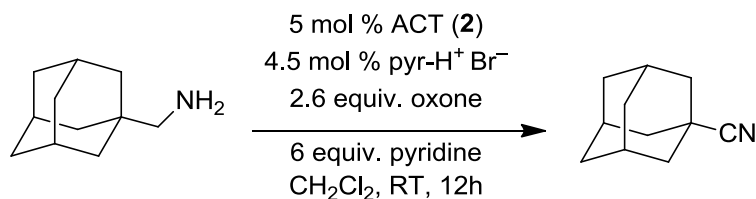


1-Adamantanecarboxamide⁴¹; Was prepared following the procedure described by Farcasiu et al.²⁴ To a dry 250 mL round bottomed flask was added 27.039 g (150.0 mmol, 1.0 equiv.) of 1-adamantanecarboxylic acid, 50 mL of dichloromethane, and a catalytic amount of dimethylformamide. Following the immediate addition of 19.631 g (165.0 mmol, 1.1 equiv.) of thionyl chloride, the flask was fitted with a Friedrich condenser equipped with an acid trap (1 M solution of sodium hydroxide) and refluxed until the evolution of hydrogen chloride gas ceased (~1.5 h). The solvent and excess thionyl chloride were then removed under reduced pressure. The crude acid chloride was dissolved in 100 mL of anhydrous tetrahydrofuran and the resulting solution was then slowly added to a flask containing 400 mL of concentrated ammonium hydroxide at 0 °C. After 1 h of stirring, the mixture was vacuum filtered and the precipitate rinsed with cold pentane. Drying under reduced pressure afforded 24.756 g (92%) of the crude title compound as a white solid: mp 188.5–191.0 °C (lit. 188–189 °C); ¹H NMR (400 MHz, CDCl₃) δ 5.55 (br s, 2H), 2.05 (s, 3H), 1.81 – 1.93 (m, 6H), 1.63 – 1.80 (m, 6H); ¹³C NMR (100 MHz, CDCl₃) δ 184.5, 40.7, 38.7, 36.6, 28.1.

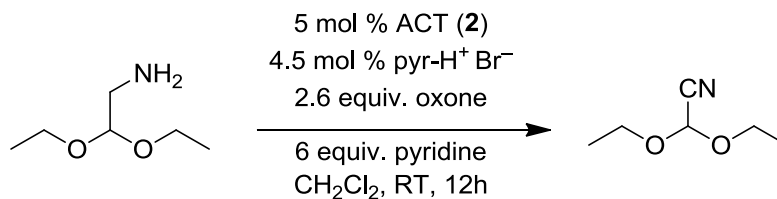


1-Adamantanemethylamine⁴²; Was prepared using the procedure outlined by Farcasiu et al.²⁴ To a dry, 500 mL round bottomed flask containing a magnetic stir bar was added 10.191 g (268.5 mmol, 2.0 equiv.) of lithium aluminum hydride and 200 mL of anhydrous tetrahydrofuran. Then 24.069 g (134.3 mmol, 1.0

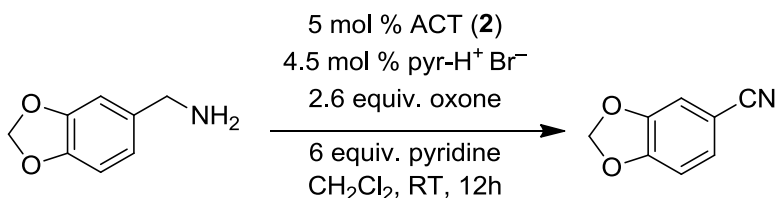
equiv.) of crude 1-adamantanecarboxamide was dissolved was dissolved in 200 mL of anhydrous tetrahydrofuran and slowly added through a condenser to the lithium aluminum hydride slurry at a rate that maintained a gentle reflux of the reaction mixture. The slurry was then refluxed by way of a constant temperature oil bath for 2 days at 65–70 °C under a nitrogen atmosphere. The reaction mixture was then cooled to room temperature and carefully quenched with 11 mL of water, 22 mL of aqueous sodium hydroxide (1 M) and an additional 11 mL of water. The mixture was filtered through a Büchner funnel and the filtrate was collected. The caked white solid was then continuously extracted overnight with diethyl ether 100 mL in a Soxhlet extractor. The organic layers (filtrate & extract) were combined and washed with 100 mL of brine, dried over sodium sulfate, and upon removal of the solvent under reduced pressure afforded 20.414 g (92%) of crude product. Distillation (Kugelrohr, bath temperature: 125 °C at 10 mm) afforded 14.739 g (72%) of the pure title compound as a clear, colorless oil: $n_D^{25} = 1.5148$ (lit. 1.4552); ^1H NMR (400 MHz, CDCl_3) δ 2.21 (br s, 2H), 1.88 (s, 3H), 1.47 – 1.69 (m, 6H), 1.36 (s, 6H), 0.84 (s, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 55.0, 40.0, 37.3, 33.9, 28.4.



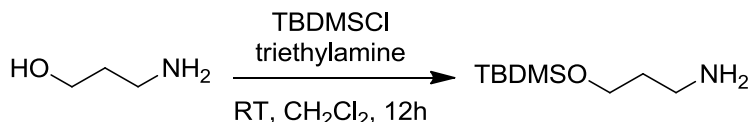
1-Adamantanecarbonitrile⁴¹ (Table 2-6, entry 18); Was prepared using the representative procedure from 1-adamantanemethylamine (1.630 g, 9.9 mmol). The isolated product was purified via sublimation (170–180 °C at 10 mm) to yield 1.415 g (89%) of the title compound as a white solid: mp 190.8–192.0 °C (lit. 191–192 °C); ^1H NMR (400 MHz, CDCl_3) δ 1.73 (s, 6H), 1.99 - 2.06 (m, 9H); ^{13}C NMR (100 MHz, CDCl_3) δ 125.4, 40.0, 35.9, 30.3, 27.2; FT-IR (cm^{-1} , neat, ATR) 2908 (s, br), 2855 (s), 2229 (w), 1733 (vw), 1453 (s), 1346 (w), 1101 (m), 977 (w), 813 (w), 693 (w); GC-MS (EI) 161 ($[\text{M}]^+$, 56%), 146 (17%), 134 (100%), 104 (18%), 93 (66%), 79 (31%), 67 (21%), 53 (15%), 41 (42%).



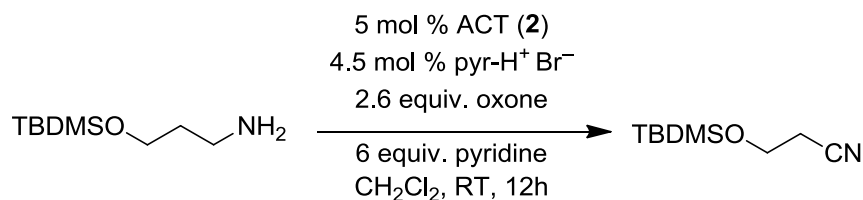
2,2-Diethoxyacetonitrile⁴³ (Table 2-6, entry 19); Was prepared using the representative procedure from 2,2-diethoxyethanamine (1.361 g, 10.2 mmol) to afford 1.228 g (93%) of the title product as a clear, colorless oil: $n_D^{25} = 1.3998$ (lit. 1.3934); ¹H NMR (400 MHz, CDCl₃) δ 5.30 (s, 1H), 3.42 (dq, $J = 9.38$ Hz, $J = 7.13$ Hz, 2H), 3.68 (dq, $J = 9.38$ Hz, $J = 7.13$ Hz, 2H), 1.26 (t, $J = 7.07$ Hz, 6H); ¹³C NMR (100 MHz, CDCl₃) δ 114.9, 89.7, 62.7, 14.8; FT-IR (cm⁻¹, neat, ATR) 2982 (m), 2936 (w), 2895 (w), 2247 (vw), 1328 (m), 1113 (m), 1060 (s), 949 (m), 913 (m), 733 (m); GC-MS (EI) 128 ([M-1]⁺, 2.7%), 114 (18%), 84 (100%), 56 (63%), 45 (52%), 31 (65%).



1,3-Benzodioxol-5-carbonitrile⁴⁴ (Table 2-6, entry 20); Was prepared using the representative procedure from 1,3-benzodioxol-5-ylmethylamine (1.512 g, 10.0 mmol) to yield 1.197 g (81 %) of the title compound as a white solid: mp 91.0–92.0 °C (lit. 91–92 °C); ¹H NMR (400 MHz, CDCl₃) δ 7.20 (d, $J = 8.00$ Hz, 1H), 7.03 (s, 1H), 6.86 (d, $J = 8.09$ Hz, 1H), 6.06 (s, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 151.7, 148.2, 128.4, 119.1, 111.6, 109.3, 105.2, 102.4; FT-IR (cm⁻¹, neat, ATR) 2918 (w), 2220 (m), 1603 (w), 1500 (s), 1441 (s), 1254 (s), 1100 (m), 1029 (s), 915 (s), 861 (s), 810 (s), 610 (s); GC-MS (EI) 147 ([M]⁺, 68%), 146 ([M-1]⁺, 100%), 62 (28%), 38 (17%).

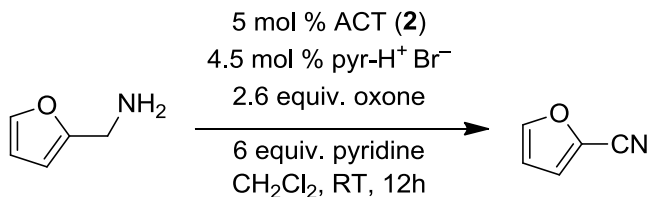


3-(*tert*-Butyldimethylsilyloxy)propanamine⁴⁵; Was prepared using the procedure outlined by Padwa et al.⁴⁵ To a dry 250 mL round bottomed flask containing a magnetic stir bar was added 3.578 g of 1-amino-3-propanol (47.6 mmol, 1.0 equiv.), 6.813 g of *tert*-butyldimethylsilyl chloride (45.2 mmol, 1.0 equiv.) and 90 mL of dichloromethane. Then 7.225 g of triethylamine (70.9 mmol, 1.5 equiv.) was dripped in via syringe, resulting in a cloudy-white solution which was stirred overnight. The work-up described in the referenced procedure was modified so that the solution was washed with water and brine until clear, dried over magnesium sulfate and concentrated under reduced pressure. The product was purified using column chromatography (2–8% methanol in dichloromethane), resulting in a yellow oil. Distillation (Kugelrohr, bath temperature: 95 °C at 10 mm) yielded 2.124 g (25%) of the title product as a colorless oil; $n_D^{25} = 1.6000$ (not previously reported in the lit.); ¹H NMR (400 MHz, CDCl₃) δ 3.67 (t, $J = 6.10$ Hz, 2H), 2.76 (t, $J = 6.76$ Hz, 2H), 1.63 (quint, $J = 6.43$ Hz, 2), 1.15 (s, 2H), 0.87 (s, 9H), 0.03 (s, 6H); ¹³C NMR (100 MHz, CDCl₃) δ 61.4, 39.6, 36.7, 26.1, 18.5, –5.18.



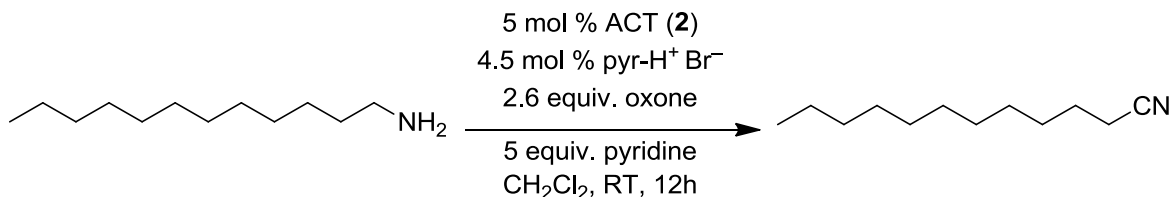
3-(*tert*-Butyldimethylsilyloxy)propionitrile⁴⁶ (Table 2-6, entry 21); Was prepared in accordance with the representative procedure from 3-(*tert*-butyldimethylsilyloxy)propanamine (1.900 g, 10.0 mmol) to afford 1.629 g (88%) of the title product as a yellow oil; $n_D^{25} = 1.6500$ (not previously reported in the lit.); ¹H NMR (400 MHz, CDCl₃) δ 3.85 (t, $J = 6.30$ Hz, 2H), 2.53 (t, $J = 6.30$ Hz), 0.90 (s, 9H), 0.09 (s, 6H); ¹³C NMR (100 MHz, CDCl₃) δ 118.2, 58.7, 25.9, 21.9, 18.4, –5.3; FT-IR (cm^{–1}, neat, ATR) 2955 (m),

2930 (m), 2885 (w), 2857 (m), 2252 (w), 1472 (m), 1254 (m), 1109 (s), 912 (m), 834 (s), 776 (s), 661 (m); GC-MS (EI) 184 ($[M-1]^+$, 0.1%), 128 (100%), 98 (60%), 73 (11%).



Tetrahydrofuran-2-carbonitrile⁴⁷ (Table 2-6, entry 22); Was prepared following the representative procedure from tetrahydrofurfurylamine (1.059 g, 10.5 mmol) to yield 950 mg (98%) of the title compound as a clear, colorless oil: $n_D^{25} = 1.4359$ (lit. 1.4351); ¹H NMR (400 MHz, CDCl₃) δ 4.68 (t, 1H), 3.89–3.99 (m, 2H), 2.21–2.26 (m, 2H), 1.94–2.16 (m, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 119.4, 69.1, 66.3, 31.6, 24.9; FT-IR (cm⁻¹, neat, ATR) 2961 (m, br), 2882 (w), 2237 (vw), 1458 (w), 1180 (w), 1058 (s), 911 (m), 816 (w), 721 (w); GC-MS (EI) 97 ($[M]^+$, 17%), 67 (25%), 42 (100%).

Scaled-up Procedure (50 mmol scale) for the Oxidation of Primary Amines to Nitriles



Dodecanenitrile. A 1-L, one-necked, round-bottomed flask is equipped with an oval Teflon[®]-coated magnetic stirbar (40 mm x 20 mm) and capped with a septum. The flask is purged with dry nitrogen gas *via* a nitrogen line inlet and an outlet fitted to a glass bubbler filled with mineral oil. While under a continuous flow of nitrogen, the flask is flame-dried then allowed to cool to room temperature. The gas inlet and outlet are detached from the flask, and the septum is quickly removed. The flask is charged with 200 mL of dichloromethane, Oxone[®] (80.0 g, 130 mmol, 2.6 equiv.), and pyridinium bromide (365 mg, 2.25 mmol, 0.045 equiv.), then the septum is immediately replaced. The heterogeneous mixture is stirred

for 15 minutes until a faint yellow color develops. Dry pyridine (20.1 mL, 19.8 g, 250 mmol, 5 equiv.) is then added *via* syringe. The reaction mixture is stirred for 1–2 min, the septum is then removed and the 4-acetamidoTEMPO catalyst **2** (533 mg, 2.50 mmol, 0.050 equiv.) is added in one portion. The septum is then replaced, and the reaction mixture, which darkens upon addition of the catalyst, is stirred for 15 minutes. The flask is then flushed with nitrogen for 5 minutes, the septum is removed and the flask is equipped with an oven-dried 500 mL pressure-equalizing, constant-rate addition funnel fitted with a septum. The nitrogen inlet and outlet lines are added through the septum of the addition funnel, and the headspace is purged for 5 minutes with nitrogen. A clean, dry 125-mL Erlenmeyer flask is charged with dodecylamine (9.24 g, 49.9 mmol, 1 equiv.) and 100 mL of dichloromethane. The Erlenmeyer flask is swirled to dissolve the amine. The nitrogen inlet and outlet lines as well as the septum on the addition funnel are removed and the homogenous solution of amine is transferred to the addition funnel through use of a glass funnel. The Erlenmeyer flask is then rinsed with an additional 10 mL of dichloromethane to assure complete transfer and to rinse any residual amine from the funnel. The glass funnel is then removed and the septum is replaced on the addition funnel. The addition funnel is adjusted so as to allow for the addition of the amine solution at a rate of 40–50 mL/h. Addition of the amine takes approximately 2–2.5 h to complete, at which point, an additional 20 mL of dichloromethane is added to the funnel and the Teflon[®] rod is removed, allowing for any residual white solid to be rinsed into the reaction flask. The addition funnel is then removed, the reaction flask is capped with a septum, and the light yellow reaction mixture is stirred at room temperature for an additional 9 hours. A 600-mL coarse porosity, sintered glass funnel is filled with 150 g of silica gel, and a small filter paper (90 mm diameter, coarse porosity) placed on top of the silica gel. The funnel is then fitted to a 1-L filter flask, set up for vacuum filtration, and the reaction mixture is poured through the filtration setup. Any residual solids within the reaction flask are transferred onto the filter paper and rinsed with an additional 300 mL of dichloromethane. The filtration should be stopped when the colored bands have moved to within 1 cm of the glass frit. The filtrate is concentrated in 100–150 mL portions by rotary evaporation (30 °C, water aspirator pressure) into a 250-mL round-bottomed flask of known tare weight. Residual solvent is removed at room temperature under

high vacuum (10 mm, 20 min) to afford dodecanenitrile (8.62 g, 95% yield, $n_D^{20} = 1.4353$, lit.⁴⁸ $n_D^{20} = 1.4361$) as a pale yellow oil. However, the title compound is known to the literature as a clear, colorless oil.⁴⁹ Colorless product is obtained by bulb-to-bulb distillation (Kugelrohr, bath temp: 168 °C, 25 mm) from the flask containing the light yellow sample to afford analytically pure dodecanenitrile (8.35 g, 92% yield, $n_D^{20} = 1.4364$, lit.⁴⁸ $n_D^{20} = 1.4361$) as a clear colorless oil: ^1H NMR (400 MHz, CDCl_3) δ 0.87 (t, $J = 6.7$ Hz, 3H), 1.18–1.36 (m, 14H), 1.40–1.46 (m, 2H), 1.65 (quintet, $J = 7.3$ Hz, 2H), 2.32 (t, $J = 7.1$ Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 14.3, 17.3, 22.9, 25.6, 28.9, 29.0, 29.5, 29.5, 29.7, 29.7, 32.1, 120.0; FT-IR (cm^{-1} , neat, ATR): 2923, 2854, 2246, 1465, 721; GC-MS (EI): 182 ($[\text{M}+1]^+$, 7%), 181 ($[\text{M}]^+$, 0.6%), 180 ($[\text{M}-1]^+$, 3%), 138 (24%), 124 (36%), 110 (59%), 97 (85%), 82 (56%), 69 (42%), 57 (62%), 41 (100%); HRMS (DART-TOF) $\text{C}_{12}\text{H}_{23}\text{N}$ $[\text{M}+\text{H}]^+$ calcd 182.1919, found 182.1909; Elemental anal. calcd for $\text{C}_{12}\text{H}_{23}\text{N}$: C 79.49, H 12.79, N 7.72, found C 79.55, H 12.95, N 7.64.

3.3 Oxidation of Alcohols and Aldehydes to Nitriles Using an Oxoammonium Salt⁵⁰

General Considerations

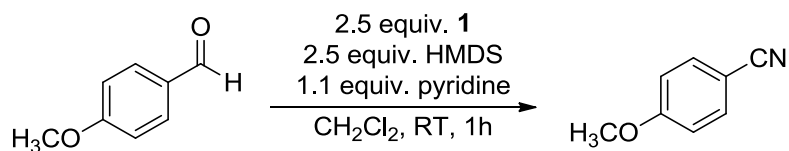
All chemical transformations requiring inert conditions were performed under a nitrogen atmosphere. NMR Spectra (^1H , ^{13}C , ^{19}F) were performed at 298 K on either a Brüker Avance Ultra Shield 300 MHz NMR, Brüker DRX-400 400 MHz NMR, or Brüker Avance 500 MHz NMR. NMR spectra (^1H , ^{13}C , ^{19}F) were recorded in CDCl_3 unless otherwise specified. Proton and carbon spectra were referenced at $\delta = 7.26$ and 77.23, respectively, for the residual ^1H resonance of the solvent and the center line of the ^{13}C adsorption of CDCl_3 and are reported relative to TMS at $\delta = 0.00$. Proton and carbon spectra obtained in $\text{DMSO}-d_6$ were referenced at $\delta = 2.50$ and 39.52, respectively, for the residual ^1H resonance of the solvent and the center line of the ^{13}C adsorption of $\text{DMSO}-d_6$ and are reported relative to TMS at $\delta = 0.00$. ^{19}F NMR spectra were recorded in CDCl_3 or $\text{DMSO}-d_6$ using hexafluorobenzene as an internal standard ($\delta = -164.9$ ppm); chemical shifts are reported relative to CCl_3F at $\delta = 0.00$.⁵¹ IR spectra were obtained on a Brüker ALPHA FT-IR spectrometer. Reactions were monitored by an Agilent Technologies 7820A Gas

Chromatograph attached to a 5975 Mass Spectrometer, ^1H NMR, and/or by TLC on silica gel plates (60Å porosity, 250 μm thickness). TLC analysis was performed using hexanes/ethyl acetate as the eluent and visualized using permanganate stain, *p*-anisaldehyde stain, Seebach's stain, and/or UV light. Flash chromatography and silica plugs utilized Dynamic Adsorbents Inc. Flash Silica Gel (60Å porosity, 32–63 μm).

Reagents

Deuterated NMR solvents (CDCl_3 , $\text{DMSO}-d_6$) were purchased from Cambridge Isotope Laboratories. CDCl_3 was stored over 4Å molecular sieves and K_2CO_3 . All reagents were ACS reagent grade or of similar quality. Silabond® Amine, used as an aldehyde scavenger was purchased from Silicycle Inc. Aldehydes were either purchased from commercial suppliers and if necessary were distilled or recrystallized before use or prepared from known procedures.⁵² Bobbitt's salt (**1**) was prepared according to the published protocol.⁵

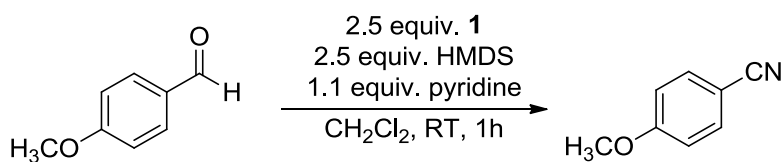
General Procedure A – Nitrile Synthesis Without Spent Oxidant Recovery



4-Methoxybenzonitrile⁴⁴; To a 100-mL round-bottomed flask equipped with a stir bar was added 1.36 g (10 mmol, 1 equiv.) of *p*-methoxybenzaldehyde, 870 mg (11 mmol, 1.1 equiv.) of pyridine, 4.04 g (5.23 mL, 25 mmol, 2.5 equiv.) of hexamethyldisilazane (HMDS) and 20 mL of dichloromethane. The slurry was stirred at room temperature for five minutes. After this time, 7.50 g (25 mmol, 2.5 equiv.) of oxoammonium salt **1** was added in one portion.^{53,54} The reaction was allowed to stir at room temperature and the solution gradually became red. Reaction completion was confirmed both by GCMS of the crude material and ^1H NMR. After the reaction was judged to be complete, the solvent was removed *in vacuo* by rotary evaporation. The solid material was suspended in 75 mL of Et_2O and the heterogeneous mixture was transferred to a separatory funnel. The solution was diluted with 200 mL of Et_2O and shaken with

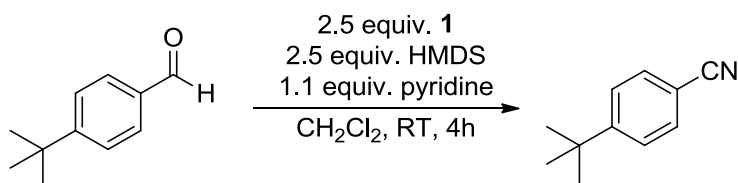
150 mL of a 2M aqueous HCl solution. The phases were separated and the organic layer was rinsed with two 100-mL portions of a 2M aqueous HCl solution, two 100-mL portions of saturated, aqueous NaHCO₃, and dried with a 150-mL portion of brine. The organic layer was dried with Na₂SO₄ and the solvent was removed *in vacuo* by rotary evaporation⁵⁵ to give 1.21g (91%) of the title compound as a crystalline white solid: ¹H NMR (CDCl₃, 500 MHz) δ ppm 3.81 (s, 3H) 6.91 (d, *J* = 9.29 Hz, 2H) 7.53 (d, *J* = 9.29 Hz, 2H); ¹³C NMR (CDCl₃, 125 MHz) δ ppm 55.6, 103.9, 114.8, 119.3, 134.00, 162.9; GC-MS (EI) 133 ([M]⁺, 74%), 118 (17%), 103 (57%), 90 (100%), 78 (11%), 75 (22%), 64 (46%), 50 (21%), 39 (17%); FT-IR (cm⁻¹, neat, ATR) 2942 (vw, b), 2843 (vw), 2216 (m), 1603 (m), 1508 (m), 1255 (m), 1173 (m), 1021 (m), 826 (m), 681 (m), 544 (m).

General Procedure B – Nitrile Synthesis With Spent Oxidant Recovery

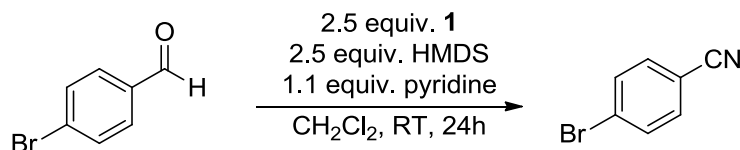


4-Methoxybenzonitrile⁴⁴ (Table 2-7, entry 1); To a 100-mL round-bottomed flask equipped with a stir bar was added 1.36 g (10 mmol, 1 equiv.) of *p*-methoxybenzaldehyde, 870 mg (11 mmol, 1.1 equiv.) of pyridine, 4.04 g (5.23 mL, 25 mmol, 2.5 equiv.) of hexamethyldisilazane (HMDS) and 20 mL of dichloromethane. The slurry was stirred at room temperature for five minutes. After this time, 7.50 g (25 mmol, 2.5 equiv.) of oxoammonium salt **1** was added in one portion.^{56,57} The reaction was allowed to stir at room temperature and the solution gradually became red. Reaction completion was confirmed both by GCMS of the crude material and ¹H NMR. After the reaction was judged to be complete, the solvent was removed *in vacuo* by rotary evaporation. The solid material was suspended in 75 mL of Et₂O and stirred vigorously at room temperature for 15 minutes; this causes immediate precipitation of nitroxide **2**. **Note:** *It is imperative that the sides of the flask be scraped to ensure 2 fully precipitates, releasing the product into solution.* The heterogeneous mixture was then filtered through a coarse fritted funnel containing a

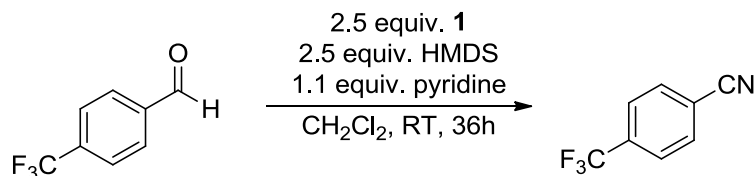
filter paper, and the resulting orange solid was rinsed with a 200-mL portion of Et₂O and the filtrate was transferred to a separatory funnel. The solution was shaken with 150 mL of a 2M aqueous HCl solution. The phases were separated and the organic layer was rinsed with two 100-mL portions of a 2M aqueous HCl solution, two 100-mL portions of saturated, aqueous NaHCO₃, and dried with a 150-mL portion of brine. The organic layer was dried with Na₂SO₄ and the solvent was removed *in vacuo* by rotary evaporation⁵⁸ to give 1.27g (95%) of the title compound as a crystalline white solid: ¹H NMR (CDCl₃, 500 MHz) δ ppm 3.81 (s, 3H), 6.91 (d, *J* = 9.29 Hz, 2H), 7.53 (d, *J* = 9.29 Hz, 2H); ¹³C NMR (CDCl₃, 125 MHz) δ ppm 55.6, 103.9, 114.9, 119.3, 134.0, 162.9; GC-MS (EI) 133 ([M]⁺, 74%) 118 (17%), 103 (57%), 90 (100%), 78 (11%), 75 (22%), 64 (46%), 50 (21%), 39 (17%); FT-IR (cm⁻¹, neat, ATR) 2942 (vw, b), 2843 (vw), 2216 (m), 1603 (m), 1508 (m), 1255 (m), 1173 (m), 1021 (m), 826 (m), 681 (m), 544 (m).



4-(tert-Butyl)benzonitrile⁵⁹ (Table 2-7, entry 2); Was prepared according to General Procedure A from 1.62 g (10 mmol) of 4-(tert-butyl)benzaldehyde affording 1.54 g (97%) of the title compound as a clear, yellow oil: ¹H NMR (CDCl₃, 300 MHz) δ ppm 1.32 (s, 9H), 7.47 (d, *J* = 8.00 Hz, 2H), 7.57 (d, *J* = 8.03 Hz, 2H); ¹³C NMR (CDCl₃, 75 MHz) δ ppm 31.1, 35.4, 109.5, 119.3, 126.4, 132.1, 156.8; GC-MS (EI) 159 ([M]⁺, 62%), 144 (100%), 128 (11%), 116 (98%), 104 (31%), 102 (9%), 89 (16%), 77 (12%), 21 (11%), 41 (21%); FT-IR (cm⁻¹, neat, ATR) 2964 (m, br), 2871 (w, br), 2227 (m), 1606 (m), 1505 (m), 1465 (m), 1270 (m), 1106 (m), 836 (s).

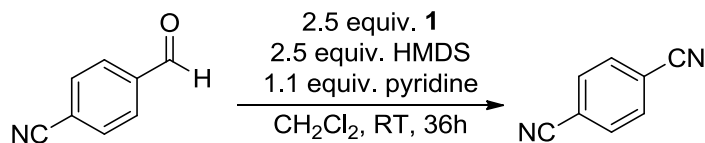


4-Bromobenzonitrile⁵⁹ (Table 2-7, entry 3); Was prepared according to General Procedure A from 1.85 g (10 mmol) of 4-bromobenzaldehyde *with the following modifications*: (1) Further purification was accomplished by silica gel plug (95:5 Hexanes/EtOAc → 9:1 Hexanes/EtOAc) (2) The crude material was diluted with 10 mL of Et₂O and stirred with 1 g of SilaBond[®] Amine overnight to remove the aldehyde by-product. Filtration and solvent removal afforded 1.37 g (75%) of the title compound as a white solid; ¹H NMR (CDCl₃, 500 MHz) δ ppm 7.53 (d, *J* = 8.32 Hz, 2H), 7.64 (d, *J* = 8.66 Hz, 2H); ¹³C NMR (CDCl₃, 125 MHz) δ ppm 111.5, 118.2, 128.2, 132.8, 133.6; GC-MS (EI) 183 ([M]⁺, ⁸¹Br, 84%), 181 ([M]⁺, ⁷⁹Br, 85%), 102 (100%), 99 (9%), 75 (48%), 50 (28%); FT-IR (cm⁻¹, neat, ATR) 3085 (w), 2224 (m), 1582 (m), 1478 (m), 1397 (m), 1066 (m), 1013 (m), 822 (s), 539 (s).

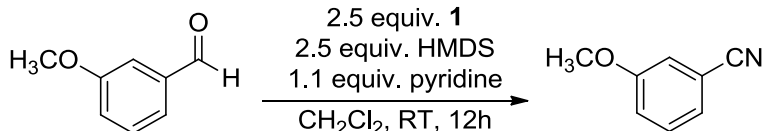


4-(Trifluoromethyl)benzonitrile⁶⁰ (Table 2-7, entry 4); Was prepared according to General Procedure A from 1.74g (10 mmol) of 4-(trifluoromethyl)benzaldehyde *with the following modifications*: (1) The reaction was conducted in a 50:50 by volume mixture of CH₂Cl₂:Et₂O (2) Further purification was accomplished by silica gel plug (95:5 Hexanes/EtOAc → 9:1 Hexanes/EtOAc) (3) The crude material was diluted with 10 mL of Et₂O and stirred with 1 g of SilaBond[®] amine overnight to remove the aldehyde by-product. Filtration and solvent removal afforded 0.864 g (51%) of the title compound as a clear, yellow oil. ¹H NMR (CDCl₃, 500 MHz) δ ppm 7.76 (d, *J* = 8.37 Hz, 2H), 7.81 (d, *J* = 8.32 Hz, 2H); ¹³C NMR (CDCl₃, 125 MHz) δ ppm 116.3 (q, *J*_{C-F} = 1.4 Hz), 117.6, 123.3 (q, *J*_{C-F} = 273.3 Hz), 126.3 (q, *J*_{C-F} 3.7 Hz), 132.9, 134.7 (q, *J*_{C-F} = 33.5 Hz); ¹⁹F NMR (CDCl₃, 377 MHz) δ ppm -66.7; GC-MS (EI) 171 ([M]⁺, 100%), 152 (54%), 122 (61%), 102 (12%), 94 (7%), 75 (22%), 69 (10%), 50 (12%);

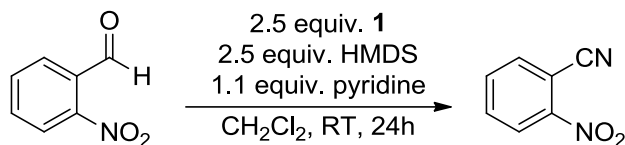
FT-IR (cm^{-1} , neat, ATR) 3108 (vw, br), 2235 (w), 1412 (w), 1316 (s), 1126 (s, br), 1063 (s), 1018 (m), 843 (s), 731 (w), 598 (m), 545 (m).



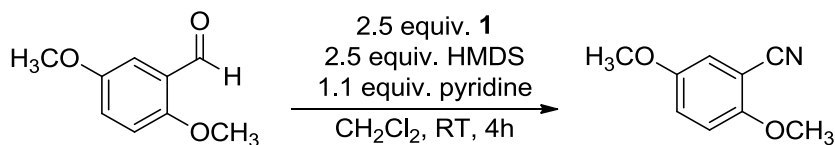
4-Cyanobenzonitrile⁵⁹ (Table 2-7, entry 5); Was prepared according to General Procedure A from 1.31g (10 mmol) of 4-cyanobenzaldehyde *with the following modifications*: (1) Further purification was accomplished by silica gel plug (9:1 Hexanes/EtOAc) (2) The crude material was diluted with 10 mL of Et_2O and stirred with 1 g of SilaBond[®] amine overnight to remove the aldehyde by-product. Filtration and solvent removal afforded 0.883 g (69%) of the title compound as an off-white solid; ^1H NMR (CDCl_3 , 400 MHz) δ ppm 7.79 (s, 4H); ^{13}C NMR (CDCl_3 , 100 MHz) δ ppm 116.9, 117.2, 133.0; GC-MS (EI) 129 ($[\text{M}+1]^+$, 10%), 128 ($[\text{M}]^+$, 100%), 101 (24%), 75 (14%), 64 (7%), 50 (15%), 40 (9%); FT-IR (cm^{-1} , neat, ATR) 3097 (w), 3053 (w), 2232 (m), 1504 (m), 1401 (w), 1277 (w), 1200 (w), 842 (s), 558 (s).



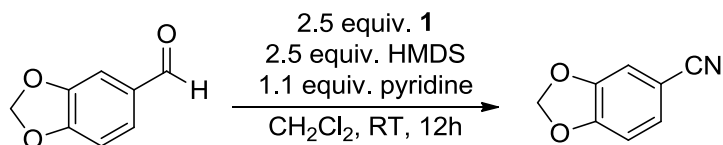
3-Methoxybenzonitrile⁶⁰ (Table 2-7, entry 6); Was prepared according to General Procedure A from 1.36 g (10 mmol) of 3-methoxybenzaldehyde to give 1.21 g (91%) of the title compound as a clear, yellow oil; ^1H NMR (CDCl_3 , 400 MHz) δ ppm 3.80 (s, 3H), 7.08 – 7.13 (m, 2H), 7.20 (d, $J = 7.34$ Hz, 1H), 7.34 (*apparent* dd, $J = 9.29$ Hz, $J = 7.82$ Hz, 1H); ^{13}C NMR (CDCl_3 , 100 MHz) δ ppm 55.6, 113.3, 117.0, 118.8, 119.4, 124.5, 130.4, 159.8; GC-MS (EI) 133 ($[\text{M}]^+$, 100%), 103 (80%), 90 (51%), 76 (19%), 63 (27%), 50 (11%), 39 (16%); FT-IR (cm^{-1} , neat, ATR) 3079 (vw), 3008 (vw), 2944 (vw, br), 2839 (vw), 2230 (m), 1578 (s), 1483 (s), 1431 (m), 1328 (m), 1289 (s), 1262 (vs), 1143 (m), 1035 (s), 873 (m), 784 (s), 680 (s), 475 (m).



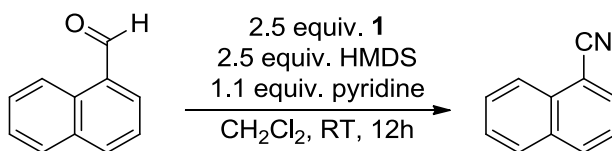
2-Nitrobenzonitrile⁶¹ (Table 2-7, entry 7); was prepared according to General Procedure A from 1.51 g (10 mmol) of 2-nitrobenzaldehyde *with the following modification*: the crude solid material was recrystallized from an 8:2 mixture of Pentane / Et₂O to afford 1.17 g (80%) of the title compound as a crystalline yellow solid; ¹H NMR (CDCl₃, 400 MHz) δ ppm 7.81–7.89 (m, 2H), 7.90–7.97 (m, 1H), 8.29–8.39 (m, 1H); ¹³C NMR (CDCl₃, 100 MHz) δ ppm 108.3, 115.2, 125.8, 134.0, 134.6, 135.9, 148.8; GC-MS (EI) 148 ([M]⁺, 0.1%), 118 (15%), 104 (10%), 102 (88%), 99 (14%), 90 (66%), 75 (100%), 63 (23%), 51 (43%), 46 (17%), 39 (15%); FT-IR (cm⁻¹, neat, ATR) 3111 (w, br), 3036 (vw), 2863 (vw), 2232 (m), 1524 (s), 1341 (s), 858 (m), 790 (m), 741 (s), 683 (m), 661 (m), 589 (m).



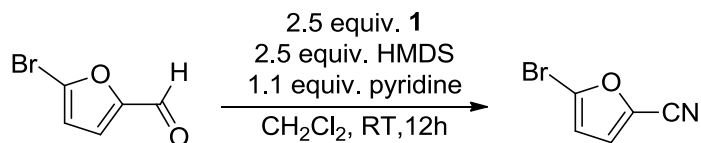
2,5-Dimethoxybenzonitrile⁶² (Table 2-7, entry 8); was prepared according to General Procedure A from 1.66 (10 mmol) of 2,5-dimethoxybenzaldehyde *with the following modifications*: the crude solid material was recrystallized from an 1:1 mixture of Pentane / Et₂O to afford 1.42 g (88%) of the title compound as pale yellow needles; ¹H NMR (CDCl₃, 300 MHz) δ ppm 3.76 (s, 3H), 3.86 (s, 3H), 6.89 (d, *J* = 9.22 Hz, 1H), 6.98–7.14 (m, 2H); ¹³C NMR (CDCl₃, 75 MHz) δ ppm 56.2, 56.6, 101.9, 112.8, 116.6, 117.8, 121.0, 153.4, 155.9; GC-MS (EI) 163 ([M]⁺, 51%), 148 (100%), 120 (87%), 92 (17%), 89 (11%), 79 (28%), 77 (21%), 65 (28%), 62 (16%), 51 (18%), 38 (7%); FT-IR (cm⁻¹, neat, ATR) 2978 (w, br), 2846 (w), 2224 (m), 1580 (m), 1504 (s), 1443 (m), 1283 (s), 1232 (s), 1159 (m), 1015 (s), 878 (m), 811 (s), 703 (m), 487 (m).



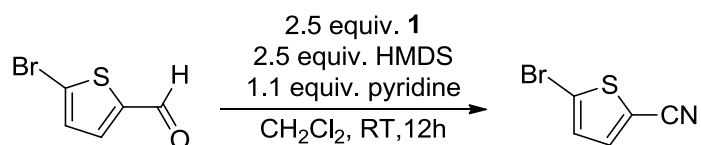
Piperonylnitrile⁴⁴ (Table 2-7, entry 9); Was prepared according to General Procedure A from 1.50 g (10 mmol) of piperonal to afford 1.37 g (93%) of the title compound as an off-white powdery solid: ¹H NMR (CDCl₃, 500 MHz) δ ppm 6.05 (s, 2H), 6.85 (d, *J* = 7.83 Hz, 1H), 7.01 (d, *J* = 0.98 Hz, 1H), 7.19 (dd, *J* = 8.07 Hz, *J* = 1.22 Hz, 1H); ¹³C NMR (CDCl₃, 125 MHz) δ ppm 102.4, 105.12, 109.3, 111.6, 119.1, 128.4, 148.3, 151.8; GC-MS (EI) 147 ([M]⁺, 68%), 146 ([M-1]⁺, 100%), 135 (8%), 89 (10%), 79 (4%), 62 (19%), 38 (8%), 32 (11%); FT-IR (cm⁻¹, neat, ATR) 2919 (vw, br), 2219 (m), 1603 (w), 1500 (s), 1441 (s), 1255 (s), 1101 (m), 1029 (s), 916 (s), 862 (s), 811 (s), 611 (s).



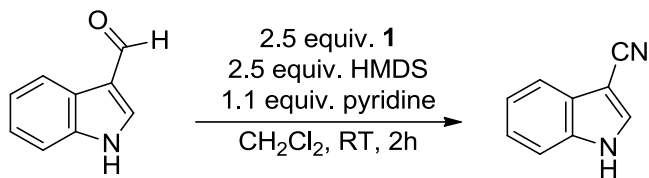
1-Naphthonitrile⁶⁰ (Table 2-7, entry 10); Was prepared according to General Procedure A from 1.56 g (10 mmol) of 1-naphthaldehyde *with the following modification*: Further purification was accomplished by silica gel plug (95:5 Hexanes/EtOAc → 9:1 Hexanes/EtOAc) to afford 1.35 g (88%) of the title compound as a clear, yellow oil: ¹H NMR (CDCl₃, 500 MHz) δ ppm 7.44 (t, *J* = 7.82 Hz, 1H), 7.56 (t, *J* = 7.40 Hz, 1H), 7.62 (td, *J* = 7.60 Hz, *J* = 1.20 Hz, 1H), 7.84 (dd, *J* = 13.00 Hz, *J* = 8.31 Hz, 2H), 7.99 (d, *J* = 8.31 Hz, 1H), 8.17 (d, *J* = 8.31 Hz, 1H); ¹³C NMR (CDCl₃, 125 MHz) δ ppm 110.1, 117.8, 124.9, 125.0, 127.5, 128.6, 128.7, 132.3, 132.6, 132.9, 133.3; GC-MS (EI) 153 ([M]⁺, 100%), 126 (21%), 99 (5%), 76 (7%), 63 (8%), 50 (6%); FT-IR (cm⁻¹, neat, ATR) 3060 (w, br), 2221 (m), 1590 (w), 1512 (m), 1375 (w), 1341 (w), 1212 (w), 799 (s), 768 (s), 448 (s).



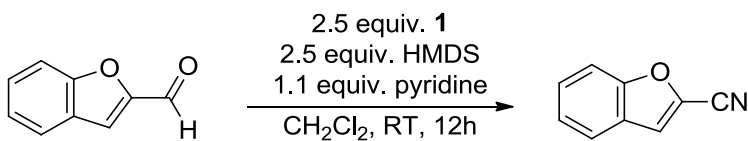
5-Bromofuran-2-carbonitrile⁶³ (Table 2-7, entry 11); Was prepared according to General Procedure A from 1.75 g (10 mmol) of 5-bromofuran-2-carbaldehyde to afford 1.40 g (82%) of the title compound as a clear, pale orange oil; ¹H NMR (CDCl₃, 400 MHz) δ ppm 6.50 (d, *J* = 3.50 Hz, 1H), 7.08 (d, *J* = 3.50 Hz, 1H); ¹³C NMR (CDCl₃, 100 MHz) δ ppm 110.7, 113.9, 124.6, 128.2, 128.5; GC-MS (EI) 173 ([M]⁺, ⁸¹Br, 55%), 171 ([M]⁺, ⁷⁹Br, 55%), 143 (4%), 122 (⁸¹Br, 7%), 120 (⁷⁹Br, 7%), 119 (⁸¹Br, 9%), 117 (⁷⁹Br, 9%), 81 (⁸¹Br, 9%), 79 (⁷⁹Br, 9%), 64 (100%), 37 (29%); FT-IR (cm⁻¹, neat, ATR) 3152 (w, br), 2231 (m), 1462 (s), 1206 (m), 1123 (m), 1017 (m), 954 (m), 791 (s), 463 (m).



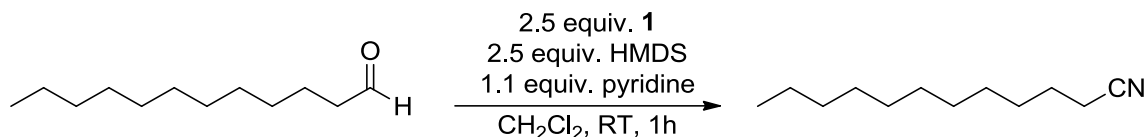
5-Bromothiophene-2-carbonitrile⁶⁴ (Table 2-7, entry 12); Was prepared according to General Procedure A from 1.91 g (10 mmol) of 5-bromothiophene-2-carbaldehyde *with the following modifications*: (1) Further purification was accomplished by a silica gel plug (95:5 Hexanes / EtOAc → 9:1 Hexanes/EtOAc) (2) The crude material was diluted with 10 mL of Et₂O and stirred with 1 g of SilaBond[®] Amine overnight to remove the aldehyde by-product. Filtration and solvent removal afforded 1.29 g (69%) of the analytically pure title compound as a clear, pale yellow oil: ¹H NMR (CDCl₃, 400 MHz) δ ppm 7.10 (d, *J* = 3.89 Hz, 1H), 7.39 (d, *J* = 4.09 Hz, 1H); ¹³C NMR (CDCl₃, 100 MHz) δ ppm 111.4, 113.2, 120.3, 130.9, 138.1; GC-MS (EI) 189 ([M]⁺, ⁸¹Br, 100%), 189 ([M]⁺, ⁷⁹Br, 100%), 138 (⁸¹Br, 14%), 136 (⁷⁹Br, 13%), 119 (⁸¹Br, 9%), 117 (⁷⁹Br, 10%), 108 (44%), 81 (18%), 69 (16%), 64 (50%), 57 (40%), 45 (20%); FT-IR (cm⁻¹, neat, ATR) 3100 (w), 2221 (s), 1410 (s), 1211 (m), 1152 (m), 971 (s), 799 (s), 686 (m), 523 (s).



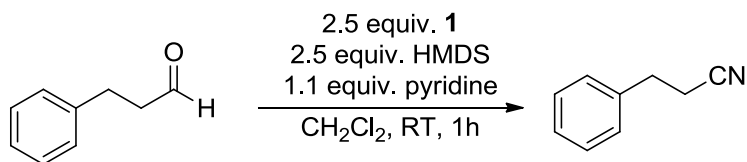
1H-indole-3-carbonitrile⁶⁵ (Table 2-7, entry 13); Was prepared according to General Procedure A from 1.45 g (10 mmol) of 1H-indole-3-carbaldehyde *with the following modification*: Further purification was accomplished by an alumina plug (8:2 Hexanes/EtOAc → 7:3 Hex/EtOAc) to yield 0.946 g (67%) of the title compound as a powdery orange solid⁶⁶: ¹H NMR (DMSO-*d*₆, 400 MHz) δ ppm 7.26 (dtd, *J* = 21.10, 7.50 Hz, *J* = 7.50 Hz, *J* = 1.31 Hz, 2H), 7.55 (d, *J* = 7.83 Hz, 1H), 7.64 (d, *J* = 7.74 Hz, 1H), 8.24 (d, *J* = 2.92 Hz, 1H), 12.19 (br. s., 1H); ¹³C NMR (DMSO-*d*₆, 100 MHz) δ ppm 84.2, 112.9, 116.4, 118.4, 121.7, 123.3, 126.7, 134.5, 135.2; GC-MS (EI) 142 ([M]⁺, 100%), 115 (47%), 88 (27%), 75 (10%), 62 (18%), 50 (10%); FT-IR (cm⁻¹, neat, ATR) 3217 (s, br), 3048 (m), 2223 (s), 1639 (m), 1524 (m), 1428 (s), 1331 (m), 1240 (s), 1107 (m), 842 (m), 738 (s, br), 602 (s), 421 (s).



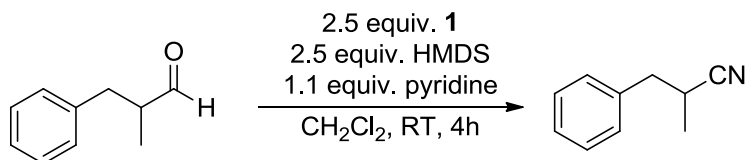
Benzofuran-2-carbonitrile⁶⁷ (Table 2-7, entry 14); Was prepared according to General Procedure A from 1.46 g (10 mmol) of benzofuran-2-carbaldehyde *with the following modification*: Further purification was accomplished by silica gel plug (95:5 Hexanes/EtOAc → 9:1 Hexanes/EtOAc) to give 1.07 g (75%) of the title compound as a clear, yellow oil that solidified upon standing; ¹H NMR (CDCl₃, 500 MHz) δ ppm 7.37 (t, *J* = 7.30 Hz, 1H), 7.46 (s, 1H), 7.48–7.59 (m, 2H), 7.68 (d, *J* = 7.88 Hz, 1H); ¹³C NMR (CDCl₃, 125 MHz) δ ppm 112.0, 112.2, 118.7, 122.8, 124.7, 125.7, 127.4, 128.6, 155.8; GC-MS (EI) 143 ([M]⁺, 100%), 115 (54%), 88 (25%), 76 (5%), 63 (18%), 51 (7%), 39 (6%), 32 (7%); FT-IR (cm⁻¹, neat, ATR) 3129 (vw, br), 2228 (m), 1612 (m), 1554 (m), 1475 (m), 1444 (m), 1179 (m), 942 (m), 822 (m), 747 (s), 628 (m), 417 (m).



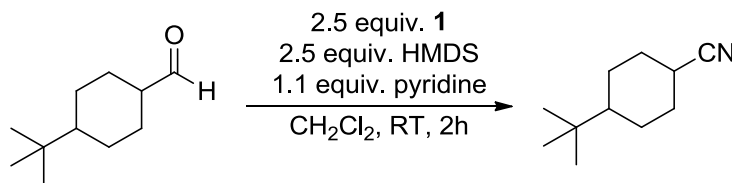
Dodecanenitrile⁶⁸ (Table 2-7, entry 15); Was prepared according to General Procedure A from 1.84 g (10 mmol) of dodecanal *with the following modification*: Further purification was accomplished by silica gel plug (95:5 Hexanes/EtOAc) to yield 1.45 g (80%) of the title compound as a clear, pale yellow oil: ¹H NMR (CDCl₃, 500 MHz) δ ppm 0.88 (t, *J* = 7.10 Hz, 3H), 1.29 (br. s, 14H), 1.44 (quintet, *J* = 7.30 Hz, 2H), 1.65 (quintet, *J* = 7.40 Hz, 2H), 2.33 (t, *J* = 7.09 Hz, 2H); ¹³C NMR (CDCl₃, 125 MHz) δ ppm 14.3, 17.3, 22.9, 25.6, 28.9, 29.0, 29.49, 29.51, 29.7, 29.8, 32.1, 112.0; GC-MS (EI) 181 ([M]⁺, 0.1%), 152 (7%), 138 (13%), 124 (18%), 110 (29%), 97 (43%), 96 (42%), 83 (27%), 82 (39%), 69 (21%), 57 (14%), 55 (44%), 54 (21%), 43 (40%), 41 (100%), 39 (35%); FT-IR (cm⁻¹, neat, ATR) 2923 (s), 2853 (m), 2246 (vw), 1657 (w, br), 1539 (w), 1465 (m), 1311 (w), 842 (w), 722 (w).



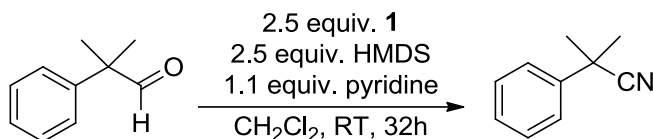
3-Phenylpropanenitrile⁶⁹ (Table 2-7, entry 16); Was prepared according to General Procedure A from 1.34 g (10 mmol) of hydrocinnamaldehyde to afford 0.93 g (71%) of the title compound as a clear, pale yellow oil: ¹H NMR (CDCl₃, 400 MHz) δ ppm 2.64 (t, *J* = 7.40 Hz, 2H), 2.99 (t, *J* = 7.40 Hz, 2H), 7.23–7.33 (m, 3H), 7.37 (tt, *J* = 7.60 Hz, *J* = 1.60 Hz, 2H); ¹³C NMR (CDCl₃, 100 MHz) δ ppm 19.5, 31.8, 119.3, 127.4, 128.5, 129.1, 138.3; GC-MS (EI) 131 ([M]⁺, 19%), 91 (100%), 77 (5%), 65 (16%), 63 (8%), 51 (10%); FT-IR (cm⁻¹, neat, ATR) 3030 (vw, br), 2932 (vw, br), 2246 (w), 1723 (w), 1454 (m), 1424 (m), 1079 (w), 747 (s), 697 (s), 589 (m), 480 (m).



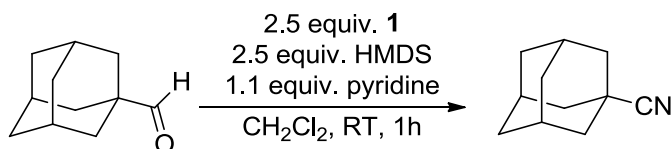
2-Methyl-3-phenylpropanenitrile⁷⁰ (Table 2-7, entry 17); Was prepared according to General Procedure A from 1.48 g (10 mmol) of 2-methyl-3-phenylpropanal to afford 1.03 g (72%) of the title compound as a clear, pale yellow oil: ¹H NMR (CDCl₃, 500 MHz) δ ppm 1.32 (d, *J* = 6.85 Hz, 3H) 2.80–2.88 (m, 2H), 2.93 (*apparent* td, *J* = 10.80 Hz, *J* = 5.38 Hz, 1H), 7.23–7.27 (m, 2H), 7.27–7.32 (m, 1H), 7.32–7.38 (m, 2H); ¹³C NMR (CDCl₃, 125 MHz) δ ppm 17.7, 27.6, 40.0, 122.6, 127.3, 128.8, 129.1, 137.0; GC-MS (EI) 145 ([M]⁺, 14%), 91 (100%), 65 (15%), 51 (5%), 39 (6%); FT-IR (cm⁻¹, neat, ATR) 3030 (vw), 2983 (vw), 2938 (vw), 2239 (vw), 1495 (m), 1454 (m), 737 (s), 698 (s), 480 (m).



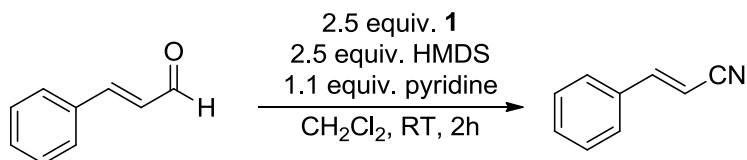
4-(*tert*-Butyl)cyclohexanecarbonitrile⁷¹ (Table 2-7, entry 18); Was prepared according to General Procedure A from 1.68 g (10 mmol) of 4-(*tert*-butyl)cyclohexanecarbaldehyde to afford 1.60 g (96%) of the title compound as a clear, pale yellow oil, which contained a (60:40) mixture of *cis* and *trans* isomers respectively: ¹H NMR (CDCl₃, 400 MHz) δ ppm *cis isomer*: 0.87 (s, 9H), 1.36 (qd, *J* = 12.80 Hz, *J* = 3.31 Hz, 2H), 1.51 (tt, *J* = 12.70 Hz, *J* = 4.30 Hz, 3H), 1.77 (*apparent* doublet, *J* = 13.23 Hz, 2H), 2.03 (*apparent* doublet, *J* = 12.65 Hz, 2H), 2.86–2.96 (m, 1H), *trans isomer*: 0.84 (s, 9H), 0.94–1.04 (m, 5H), 1.81–1.89 (m, 2H), 2.11–2.20 (m, 2H), 2.31 (tt, *J* = 12.50 Hz, *J* = 3.70 Hz, 1H); ¹³C NMR (CDCl₃, 100 MHz) δ ppm *cis isomer*: 26.4, 27.5, 28.5, 29.2, 32.6, 47.0, 122.4, *trans isomer*: 23.6, 27.3, 27.6, 30.7, 32.7, 47.8, 123.1; GC-MS (EI) *cis isomer*: 165 ([M]⁺, 1%), 150 (23%), 109 (48%), 94 (18%), 92 (13%), 81 (29%), 67 (21%), 57 (100%), 55 (14%), 43 (14%), 51 (55%), *trans isomer*: 165 ([M]⁺, 0.1%), 150 (12%), 110 (21%), 81 (14%), 67 (10%), 57 (100%), 53 (9%), 41 (40%); FT-IR (cm⁻¹, neat, ATR) 2944 (s, br), 2864 (m), 2237 (w), 1450 (m), 1366 (m), 1239 (w), 902 (w).



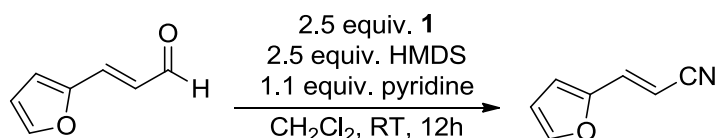
2-Methyl-2-phenylpropanenitrile⁷² (Table 2-7, entry 19); Was prepared according to General Procedure A from 1.48 g (10 mmol) of 2-phenyl-2-methylpropanal *with the following modification*: The crude material was diluted with 10 mL of Et₂O and stirred with 0.5 g of SilaBond[®] Amine overnight to remove the aldehyde by-product. Filtration and removal of the solvent under reduced pressure afforded 1.15 g (80%) of the title compound as a clear, colorless oil: ¹H NMR (CDCl₃, 300 MHz) δ ppm 1.74 (s, 6H), 7.32 (t, *J* = 7.10 Hz, 1H), 7.40 (t, *J* = 7.58 Hz, 2H), 7.49 (d, *J* = 7.44 Hz, 2H); ¹³C NMR (CDCl₃, 75 MHz) δ ppm 29.4, 37.4, 124.8, 125.3, 128.1, 129.2, 141.7; GC-MS (EI) 145 ([M]⁺, 3%), 130 (100%), 115 (8%), 103 (75%), 91 (10%), 77 (41%), 63 (13%), 51 (31%), 39 (14%); FT-IR (cm⁻¹, neat, ATR) 2982 (w, br), 2237 (vw), 1495 (m), 1448 (m), 1105 (w), 762 (s), 697 (s), 519 (m).



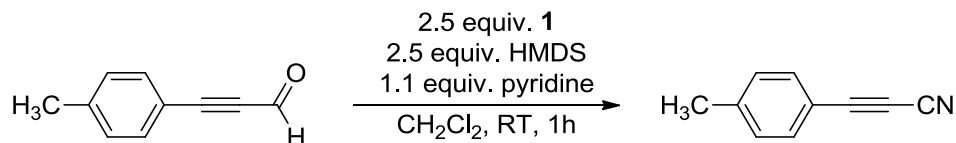
1-Adamantanecarbonitrile⁴¹ (Table 2-7, entry 20); Was prepared according to General Procedure A from 1.64 g (10 mmol) of adamantane-1-carbaldehyde to afford 1.33 g (82%) of the title compound as a white powdery solid⁷³: ¹H NMR (CDCl₃, 400 MHz) δ ppm 1.68–1.78 (m, 6H), 1.99–2.07 (m, 9H); ¹³C NMR (CDCl₃, 100 MHz) δ ppm 27.2, 30.3, 35.9, 40.0, 125.3; GC-MS (EI) 161 ([M]⁺, 59%), 146 (24%), 134 (100%), 119 (19%), 107 (10%), 106 (11%), 105 (24%), 104 (27%), 95 (26%), 34 (37%), 93 (74%), 92 (15%), 91 (33%), 79 (54%), 77 (48%), 67 (21%), 65 (23%), 53 (25%), 41 (38%), 39 (58%); FT-IR (cm⁻¹, neat, ATR) 2908 (s, br), 2855 (s), 2229 (w), 1721 (w), 1454 (s), 1346 (w), 1101 (m), 977 (w), 813 (w), 693 (w).



Cinnamonitrile³² (Table 2-7, entry 21); Was prepared according to General Procedure A from 1.32 g (10 mmol) of *trans*-cinnamaldehyde to give 1.11 g (81%) of the title compound as a clear, pale yellow oil: ¹H NMR (CDCl₃, 400 MHz) δ ppm 5.89 (d, *J* = 16.74 Hz, 1H), 7.39 (d, *J* = 16.74 Hz, 1H), 7.42–7.49 (m, 5H); ¹³C NMR (CDCl₃, 100 MHz) δ ppm 96.5, 118.3, 127.5, 129.2, 131.3, 133.6, 150.6; GC-MS (EI) 129 ([M]⁺, 100%), 102 (48%), 78 (14%), 77 (10%), 76 (17%), 75 (14%), 74 (11%), 63 (13%), 51 (23%), 39 (9%); FT-IR (cm⁻¹, neat, ATR) 3059 (vw, br), 2216 (m), 1617 (m), 1494 (w), 1448 (w), 1207 (w), 964 (m), 745 (s), 687 (s), 436 (m).



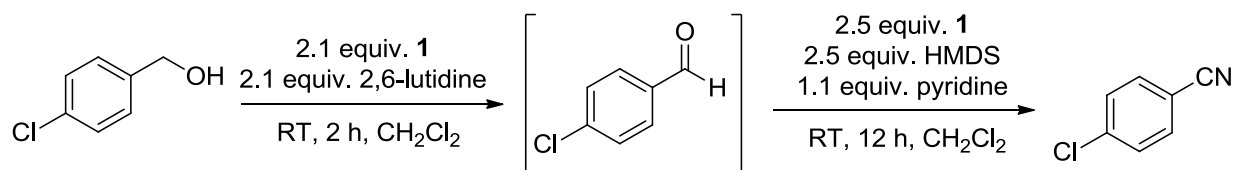
3-(Furan-2-yl)acrylonitrile⁷⁴ (Table 2-7, entry 22); Was prepared according to General Procedure A from 1.22 g (10 mmol) of 3-(2-Furyl)acrolein to yield 0.930 g (78%) of the title compound as a pale brown oil, which solidified to a tan solid upon standing: ¹H NMR (CDCl₃, 400 MHz) δ ppm 5.75 (d, *J* = 16.15 Hz, 1H), 6.50 (dd, *J* = 3.41 Hz, *J* = 1.85 Hz, 1H), 6.63 (d, *J* = 3.31 Hz, 1H), 7.11 (d, *J* = 16.15 Hz, 1H), 7.50 (d, *J* = 1.36 Hz, 1H); ¹³C NMR (CDCl₃, 100 MHz) δ ppm 93.5, 112.8, 115.7, 118.4, 136.3, 145.7, 150.0; GC-MS (EI) 119 ([M]⁺, 100%), 92 (12%), 90 (38%), 64 (43%), 63 (32%), 52 (11%), 39 (18%); FT-IR (cm⁻¹, neat, ATR) 2226 (m), 1620 (s), 956 (m), 880 (s), 710 (s).



3-(*p*-Tolyl)propiolonitrile⁷⁵ (Table 2-7, entry 24); Was prepared according to General Procedure A from 1.44 g (10 mmol) 3-(*p*-Tolyl)propionaldehyde *with the following modification*: Further purification was accomplished by silica gel plug (95:5 Hexanes/EtOAc → 9:1 Hexanes/EtOAc) to afford 1.11 g

(79%) of the title compound as a pale orange crystalline solid: ^1H NMR (CDCl_3 , 400 MHz) δ ppm 2.41 (s, 3H), 7.22 (d, $J = 7.93$ Hz, 2H), 7.50 (d, $J = 8.22$ Hz, 2H); ^{13}C NMR (CDCl_3 , 100 MHz) δ ppm 22.2, 63.0, 83.8, 105.9, 114.7, 129.9, 133.7, 143.1; GC-MS (EI) 141 ($[\text{M}]^+$, 83%), 140 ($[\text{M}-1]^+$, 100%), 114 (38%), 88 (11%), 63 (9%), 50 (6%), 38 (9%); FT-IR (cm^{-1} , neat, ATR) 3044 (vw, br), 2922 (vw, br), 2258 (m), 2220 (m), 1603 (m), 1508 (m), 813 (s), 528 (s), 489 (m), 417 (m).

One Pot Procedure for Nitrile Synthesis from Alcohols Using Bobbitt's salt (1)

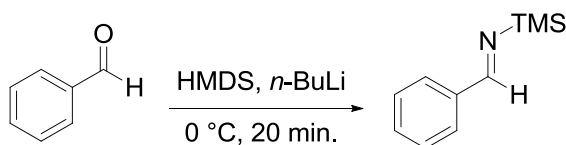


4-Chlorobenzonitrile⁷⁵ (Scheme 2-20) *First Oxidation:* To a one-neck 250-mL round-bottomed flask equipped with stirbar was added 7.50 g (25 mmol, 2.5 equiv.) of oxoammonium salt **1**, 1.43 g (10 mmol, 1 equiv.) of *p*-chlorobenzyl alcohol, 2.41 g (22.5 mmol, 2.25 equiv.) of 2,6-lutidine and 20 mL of dichloromethane solvent (0.5 M solution). The flask was sealed with a rubber septum and the yellow slurry stirred at room temperature. Reaction progress was assessed by ^1H NMR and the reaction was judged complete after 2 h. At this time, the second oxidation was initiated. *Second Oxidation:* The flask was charged with an 20 mL of additional dichloromethane solvent. Then 870 mg (11 mmol, 1.1 equiv.) of pyridine and 4.04 g (5.23 mL, 25 mmol, 2.5 equiv.) of HMDS was added to the reaction mixture, followed by the addition of 7.50 g (25 mmol, 2.5 equiv.) of oxoammonium salt **1**. The reaction was allowed to stir at room temperature and the solution gradually became red. Reaction completion was confirmed both by GC-MS and ^1H NMR analysis of the crude reaction mixture. After 12 h, the reaction was judged to be complete and the solvent was removed *in vacuo* by rotary evaporation. The solid material was suspended in 75 mL of Et_2O and the heterogeneous mixture was transferred to a separatory funnel. The solution was diluted with 200 mL of Et_2O and shaken with 150 mL of a 2M aqueous HCl solution. The phases were separated and the organic layer was rinsed with two 100-mL portions of a 2M aqueous HCl solution, two 100-mL portions of saturated, aqueous NaHCO_3 , and dried with a 150-mL

portion of brine. The organic layer was dried with Na₂SO₄ and the solvent was removed *in vacuo* by rotary evaporation to give 1.21g (91%) of the title compound as an off-white powdery solid: ¹H NMR (CDCl₃, 400 MHz) δ ppm 7.45 (d, *J* = 8.31 Hz, 2H), 7.59 (d, *J* = 8.80 Hz, 2H); ¹³C NMR (CDCl₃, 100 MHz) δ ppm 110.99, 118.14, 129.88, 133.57, 139.72; GC-MS (EI) 139 ([M]⁺, ³⁷Cl, 37%), 137 ([M]⁺, ³⁵Cl, 100%), 102 (33%), 76 (14%), 75 (28%), 50 (20%), 32 (10%); FT-IR (cm⁻¹, neat, ATR) 3091 (vw), 2224 (m), 1592 (m), 1482 (m), 1397 (m), 1086 (m), 825 (s), 541 (s).

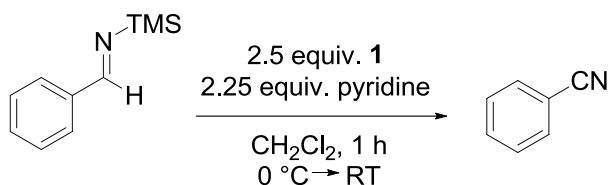
Mechanistic Study of the Oxidation of Aldehydes and Alcohols to Nitriles by an Oxoammonium

Salt in the Presence of HMDS



N-benzylidene-1,1,1-trimethylsilanamine.⁷⁶ The following is a modification of the procedure of Hart⁷⁷ et al. To a flame-dried 100-mL round bottomed flask equipped with a stir bar was added 5 mL of anhydrous THF and 8.07 g (10.50 mL, 50 mmol, 1 equiv.) of HMDS. The flask was cooled to 0 °C for five minutes *via* an ice-water bath and placed under an argon atmosphere. After this time, 25 mL (50 mmol, 1 equiv.) of a 2.0 M solution of *n*-BuLi in hexanes was added to the reaction mixture *via* cannula over a period of five minutes to allow for a slow drop-wise addition. After the addition of *n*-BuLi, the reaction mixture was stirred for five minutes before the ice bath was removed to allow the reaction mixture to warm to room temperature over a period of ten minutes. Then the solvent was slowly removed *in vacuo* by rotary evaporation until a white precipitate formed. At which point, the flask was placed under an argon atmosphere and cooled to 0 °C *via* an ice-water bath. The flask was then charged with 5.30 g (50 mmol, 1 equiv.) of acid-free benzaldehyde dissolved in 5 mL of THF. The solution was then allowed to stir for five minutes then the ice-water bath was removed, and the flask was allowed to warm to room temperature and stirred for 15 minutes. Removal of the solvent by rotary evaporation afforded a crude oil containing the imine product. Further purification was accomplished by vacuum distillation (43–45 °C at 0.1 mm) to give 3.95 g (40%) of the title compound as a clear, yellow oil: ¹H NMR (CDCl₃, 400

MHz) δ ppm 0.29 (s, 9H), 7.39–7.49 (m, 3H), 7.77–7.87 (m, 2H), 9.01 (s, 1H); ^{13}C NMR (CDCl_3 , 100 MHz) δ ppm –0.89, 128.7, 128.8, 131.5, 139.1, 168.7; GC-MS (EI) 177 ($[\text{M}]^+$, 43%), 162 (100%), 135 (30%), 105 (27%), 77 (31%), 73 (52%), 59 (59%), 51 (22%), 45 (14%), 43 (24%).



Benzonitrile.⁷⁸ To a 50-mL round-bottomed flask equipped with a stir bar was added 20 mL of dichloromethane, 1.78 g (22.5 mmol, 2.25 equiv.) of pyridine, and then 1.77 g (10 mmol, 1 equiv.) of *N*-benzylidene-1,1,1-trimethylsilanimine. The solution was cooled to 0 °C *via* an ice-water bath and stirred for five minutes. After this time, 7.50 g (25 mmol, 2.5 equiv.) of oxoammonium salt **1** was added slowly to the flask and the solution rapidly became red. After five minutes, the ice-water bath was removed and the reaction mixture was stirred for 1 h at room temperature. Reaction progress was assessed by ^1H NMR and the reaction was judged complete after this time. The solvent was then removed *in vacuo* by rotary evaporation. The solid material was suspended in 75 mL of Et_2O and the heterogeneous mixture was transferred to a separatory funnel. The solution was diluted with 200 mL of Et_2O and shaken with 150 mL of a 2M aqueous HCl solution. The phases were separated and the organic layer was rinsed with two 100-mL portions of a 2M aqueous HCl solution, two 100-mL portions of saturated, aqueous NaHCO_3 , and dried with a 150-mL portion of brine. The organic layer was dried with Na_2SO_4 and the solvent was removed *in vacuo* by rotary evaporation to give a crude oil. The crude oil was diluted with 10 mL of Et_2O and stirred with 0.5 g of *SilaBond*[®] Amine overnight to remove the aldehyde by-product⁷⁹. Filtration and solvent removal afforded 920 mg (89%) of the title compound as a clear, colorless oil; ^1H NMR (CDCl_3 , 400 MHz) δ ppm 7.44 (t, J = 7.60 Hz, 2H), 7.52–7.67 (m, 3H); ^{13}C NMR (CDCl_3 , 100 MHz) δ ppm 112.3, 118.7, 129.0, 132.0, 132.7; GC-MS (EI) 103 ($[\text{M}]^+$, 100%), 76 (38%), 75 (23%), 74 (14%), 63 (9%), 50 (32%), 37 (11%); FT-IR (cm^{-1} , neat, ATR) 3066 (vw, br), 2228 (m), 1490 (m), 1447 (m), 755 (s), 685 (s), 546 (s).

3.4 Enhancing the Reactivity of TEMPO-derived Oxoammonium Salts: A Simple Electronic Modification Increases the Rate of Alcohol Oxidations

General Considerations

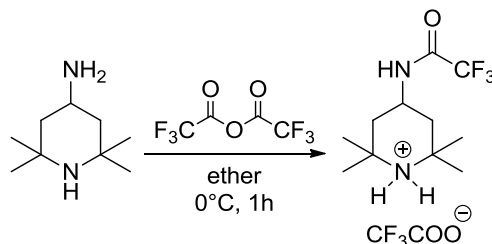
All reactions were carried out in clean, dried glassware. NMR spectra (^1H , ^{13}C , ^{19}F) were recorded in either deuterated acetonitrile containing 1 v/v% tetramethylsilane, a solution of 70% trifluoroacetic acid / 30% deuterated chloroform, or a solution of 70% acetic acid / 30% deuterated chloroform, as noted below, on a Bruker DRX-400 400 MHz NMR spectrometer, and chemical shifts are reported in parts per million (ppm). ^1H and ^{13}C NMR spectra were referenced at $\delta = 7.26$ and 77.23 , respectively, for the residual ^1H resonance of the solvent and the center line of the ^{13}C adsorption for deuterated chloroform or at $\delta = 0.00$ for the ^1H or ^{13}C resonance of TMS. Chemical shifts are reported relative to TMS at $\delta = 0.00$. ^{19}F NMR spectra were recorded in the appropriate non-fluorinated solvent, as noted below, with fluorobenzene used as an internal standard ($\delta = -113.15$), and chemical shifts are reported relative to CCl_3F at $\delta = 0.00$. UV-Vis spectra were recorded on a Cary 60 spectrophotometer from Agilent Technologies (version 2.00) scanning from 550–350 nm at a rate of 4600 or 9600 nm/min. The baseline was corrected prior to obtaining experimental readings. Acetonitrile solvent was dried over calcium hydride and distilled directly prior to use. Oxoammonium salts were dried overnight in a drying pistol at 56°C (acetone, 30 mmHg) prior to use. Melting points are not corrected.

Rate Studies

UV-Vis spectra were recorded during the oxidation of a variety of alcohols by the oxoammonium salts to allow for the determination of the rate of oxidation of each salt. A typical UV-Vis experiment was conducted as follows: to a dry 100-mL volumetric flask was added 147.2 mg of Bobbitt's salt (**1**), 168.3 mg of the 4-trifluoromethylacetamido derivative (**5**), and 100 mL of dry acetonitrile solvent. The mixture was sonicated for 2-3 minutes to ensure the oxoammonium salts were completely dissolved affording the stock solution of oxoammonium salts **1** and **5** to be used for the rate studies. The UV-Vis spectrum was taken of this stock solution to measure an initial absorbance reading. The alcohol substrate

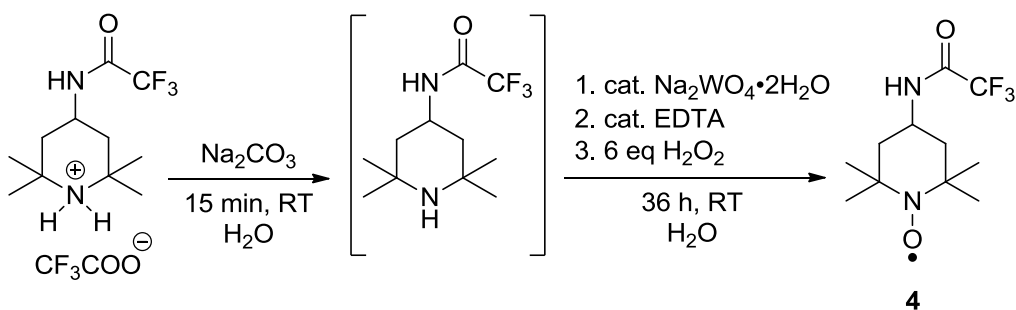
(0.50 mmol) was added to a clean, dry 3.5 mL x 10 mm x 10 mm quartz cuvette, the cuvette was placed in the UV-Vis spectrophotometer,^{80, 81} and an accurately measured 2.50 mL of the stock solution was quickly added to the cuvette. The UV-Vis spectrum was recorded for a given period of time (5.76 s – 300 s) depending on the substrate and rate of oxidation.⁸² The first UV-Vis spectrum recorded during the oxidation was treated as the initial reading (t = 0 s). Any inconsistencies between the initial absorbance readings of the oxidation and those of the stock solution were accounted for by subtracting the two, and then subtracting this difference from all absorbance readings measured to afford a “corrected absorbance reading” at each time (t). This corrected reading was used in the least squares analysis as described by Harris.⁸⁵ The UV-Vis spectra for all oxidations along with the plots of ln ([1]) vs. time (s) and ln ([5]) vs. time (s) for all substrates investigated can be found below. The rate of oxidation was determined from the slope of the linear least squares fit of these data.

Synthesis of Novel Oxoammonium Salts and Derivatives



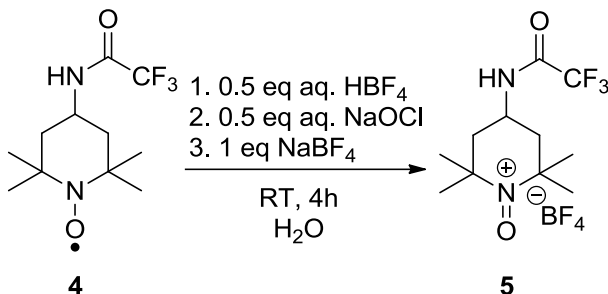
2,2,6,6-Tetramethyl-4-(2,2,2-trifluoroacetamido)piperidin-1-ium 2,2,2-trifluoroacetate. To a 1.5-L Erlenmeyer flask equipped with a large stirbar was added 78.14 g (500 mmol) of 4-amino-2,2,6,6-tetramethylpiperidine and 400 mL of diethyl ether. The solution was then cooled to 0 °C by placing the flask in an ice/water bath, and stirring was initiated. An addition funnel was fitted to the flask and a solution of 126.0 g (600 mmol) of trifluoroacetic anhydride dissolved in 100 mL of diethyl ether was added dropwise to the flask over the course of 1 h. Upon addition of the anhydride a white precipitate forms. After, stirring for an additional 1 h, the mixture was poured through a Büchner funnel. The resulting off-white solid in the filter was rinsed with an additional 200-mL portion of diethyl ether, isolated, and dried in a vacuum oven at 120 °C to afford 180.7 g (99%) of the title compound as a white,

powdered solid: mp: 256 °C (dec.), [lit.⁸³ mp 220 °C, (dec.)]; ¹H NMR (400 MHz, CD₃CN) δ 1.43 (s, 6H), 1.50 (s, 6H), 1.75 (t, *J* = 13.0 Hz, 2H), 1.96 (*J* = 3.8 Hz, *J* = 13.0 Hz, 2H), 4.23–4.33 (m, 1H), 7.74 (d, *J* = 5.3 Hz, 1H); ¹³C NMR (100 MHz, CD₃CN) δ 25.0, 30.5, 40.7, 42.8, 58.1, 117.0 (q, *J*_{C-F} = 287.6 Hz), 118.1 (q, *J*_{C-F} = 294.6 Hz), 157.4 (q, *J*_{C-F} = 36.7 Hz), 161.2 (q, *J*_{C-F} = 33.5 Hz); ¹⁹F NMR (376 MHz, CD₃CN) δ -74.2 (3F), -74.7 (3F); HRMS (DART-TOF) *m/z* calcd for C₁₁H₂₀F₃N₂O [M – CF₃COO]⁺ 253.1528, found 253.1522.



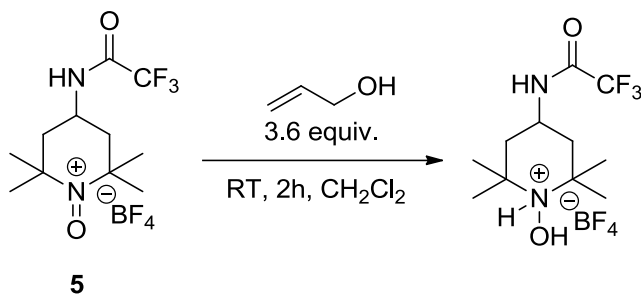
2,2,6,6-Tetramethyl-4-(2,2,2-trifluoroacetamido)piperidine-1-oxyl (4). To a 2-L beaker equipped with a large magnetic stir bar was added 176.0 g (0.48 mol) of 2,2,6,6-tetramethyl-4-(2,2,2-trifluoroacetamido)piperidin-1-ium 2,2,2-trifluoroacetate and 600 mL of deionized water. The slurry was allowed to stir for 10 min, and then 71.01 g (0.67 mol) of solid sodium carbonate was added in portions over 30 min.⁸⁴ After the solution reached a pH ~ 9, 8.59 g (260 mmol) of the sodium tungstate dihydrate catalyst and 12.07 g (290 mmol) of EDTA were added to the mixture, followed by the slow addition of 360 mL (3.2 mol) of a 30 wt% aqueous solution of hydrogen peroxide over period of 3 h. The reaction mixture was stirred vigorously for 12 h, then an additional 120 mL (1.1 mol) of the hydrogen peroxide solution was added dropwise over 2 h, and stirred for an additional 24 h. At this point, the orange reaction mixture was cooled to -10 °C in an ice/salt bath and filtered through a large Büchner funnel to afford 107.5 g (83%) of the title compound as a crude orange solid.⁸⁵ Recrystallization was accomplished as follows: the crude orange solid was dissolved in 200 mL of warm ethyl acetate, the hot solution was filtered, and then allowed to cool to room temperature. After initial crystal formation at room temperature, the flask is then cooled to 0 °C in an ice/water bath to promote further crystallization. The cold mixture is

then filtered through a Büchner funnel to afford 46.6 g (36%) of the title compound as a glistening, orange-red, crystalline solid: mp 149.6–151.8 °C, (lit.⁸³ mp 149–152 °C); HRMS (DART-TOF) m/z calcd for $C_{11}H_{18}F_3N_2O_2$ $[M]^+$ 267.1320, found 267.1335.



2,2,6,6-Tetramethyl-4-(2,2,2-trifluoroacetamido)-1-oxo-piperidinium tetrafluoroborate (5). To a 250-mL beaker containing a magnetic stir bar was added 20.00 g (74.9 mmol) of 2,2,6,6-tetramethyl-4-(2,2,2-trifluoroacetamido)piperidine-1-oxyl (**4**) and 50 mL of deionized water. To this slurry was added 15.0 mL (7.50 g, 85.4 mmol) of a 50 wt% aqueous solution of tetrafluoroboric acid dropwise over the course of 15 min. The mixture was stirred for ~ 0.5 h until the solution was a yellow color, at which point, 33.8 mL (2.79 g, 37.4 mmol, NaOCl) of an 8.25 wt% solution of commercial bleach was added dropwise to the vigorously stirred mixture over a period of 0.5 h. After the addition of bleach, 8.22 g (74.9 mmol) of sodium tetrafluoroborate was added and the reaction mixture was stirred for an additional 1 h. The reaction mixture was then cooled to –10 °C in an ice/NaCl/water bath and filtered through a large Büchner funnel to afford a crude yellow solid. The solid was dried in a drying pistol overnight, acetone (56°C, 30 mmHg), to yield 19.30 g (73%) of the title compound in greater than 90% purity. Further purification is accomplished by recrystallizing the crude material. The crude yellow solid was dissolved in 40 mL of water at 90 °C, the hot solution was quickly filtered, cooled to room temperature and then to –10 °C in an ice/NaCl/water bath. The cold slurry was filtered through a Büchner funnel and the resulting yellow solid was rinsed with 75 mL of dry diethyl ether, and dried in a drying pistol overnight, acetone (56°C, 30 mmHg), to yield 11.04 g (55%) of the title compound as a yellow crystalline solid⁸⁶: mp 160 °C (dec.); ¹H NMR (400 MHz, 70% CF_3COOH / 30% $CDCl_3$) δ 1.64 (s, 6H), 2.03 (s,

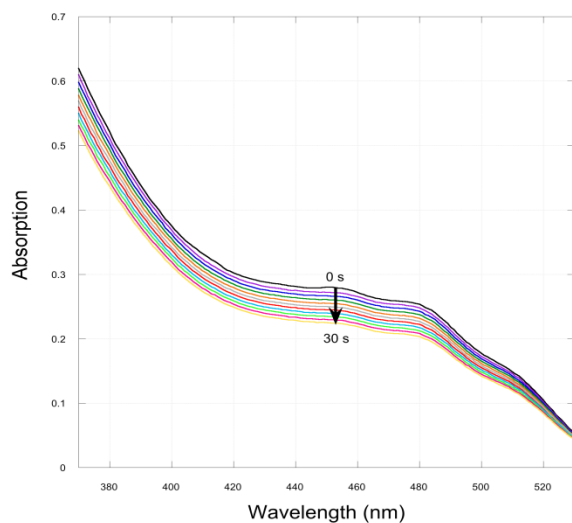
6H), 2.84 (apparent dd, $J = 4.0$ Hz, $J = 14.1$ Hz, 2H), 2.97 (t, $J = 13.1$ Hz, 2H), 5.37–5.47 (m, 1H), 8.12 (d, $J = 7.2$ Hz, 1H); ^{13}C NMR (100 MHz, 70% CF_3COOH / 30% CDCl_3) δ 28.4, 32.4, 41.2, 43.3, 104.3, 115.5 (q, $J_{\text{C-F}} = 285.4$ Hz), 160.3 (q, $J_{\text{C-F}} = 39.6$ Hz); ^{19}F NMR (376 MHz, 70% CH_3COOH / 30% CDCl_3) δ -75.5 (3F), -148.1 (4F); HRMS (DART-TOF) m/z calcd for $\text{C}_{11}\text{H}_{18}\text{F}_3\text{N}_2\text{O}_2$ $[\text{M} - \text{BF}_4]^+$ 267.1320, found 267.1336.



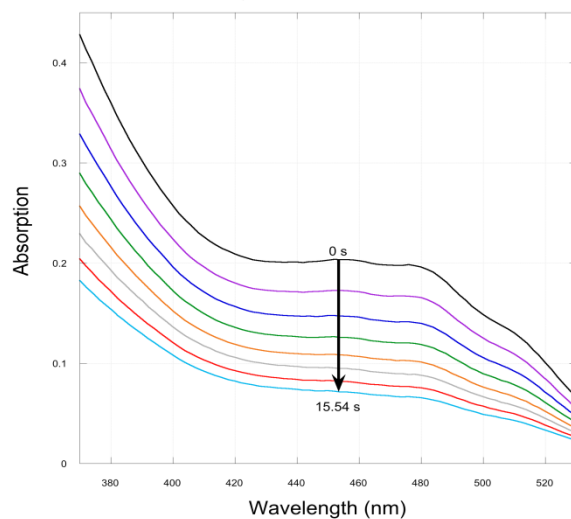
1-Hydroxy-2,2,6,6-tetramethyl-4-(2,2,2-trifluoroacetamido)piperidin-1-ium tetrafluoroborate. To a 50-mL round bottom flask was added 618 mg (1.7 mmol) of 2,2,6,6-tetramethyl-4-(2,2,2-trifluoroacetamido)-1-oxo-piperidinium tetrafluoroborate (**5**), 364 mg (6.3 mmol) of allyl alcohol and 30 mL of dichloromethane solvent. The reaction mixture was stirred for 2 h at room temperature until the solution became colorless, at which point, the solution was tested with KI starch paper and produced a negative result indicating the reaction had gone to completion. The solvent and excess alcohol was removed under reduced pressure to afford 537 mg (87%) of the title compound as a white solid: mp 170 °C (dec.); ^1H NMR (400 MHz, CD_3CN) δ 1.46 (6H), 1.47 (6H), 1.98 (t, $J = 13.2$ Hz, 2H), 2.21 (apparent dd, $J = 2.4$ Hz, $J = 13.4$ Hz, 2H), 4.25–4.35 (m, 1H), 7.66 (br s, 1H), 8.98 (br s, 1H); ^{13}C NMR (100 MHz, CD_3CN) δ 20.1, 28.0, 41.3, 41.7, 70.7, 116.9 (q, $J_{\text{C-F}} = 287.8$ Hz), 157.5 (q, $J_{\text{C-F}} = 37.4$ Hz); ^{19}F NMR (376 MHz, CD_3CN) δ -74.8 (3F), -149.0 (3F); HRMS (DART-TOF) m/z calcd for $\text{C}_{11}\text{H}_{20}\text{F}_3\text{N}_2\text{O}_2$ $[\text{M} - \text{BF}_4]^+$ 269.1477, found 269.1463.

UV-Vis Spectra for Alcohol Oxidations in CH_3CN

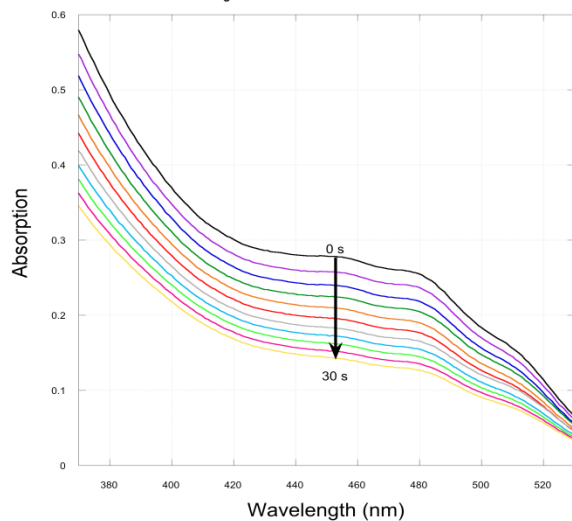
UV-Vis Spectrum for the Oxidation of Benzyl Alcohol 0 to 30s



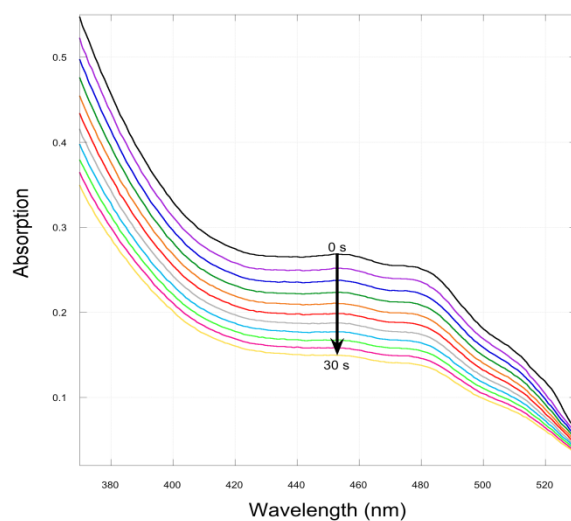
UV-Vis Spectrum for the Oxidation of $p\text{-OCH}_3$ Benzyl Alcohol 0 to 15.54s



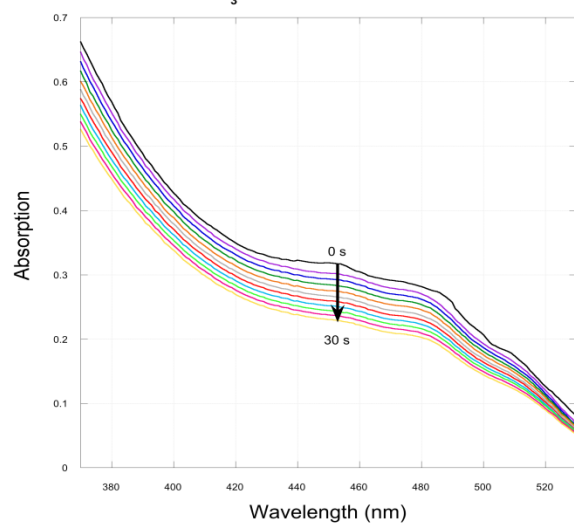
UV-Vis Spectrum for the Oxidation of $p\text{-CH}_3$ Benzyl Alcohol 0 to 30s



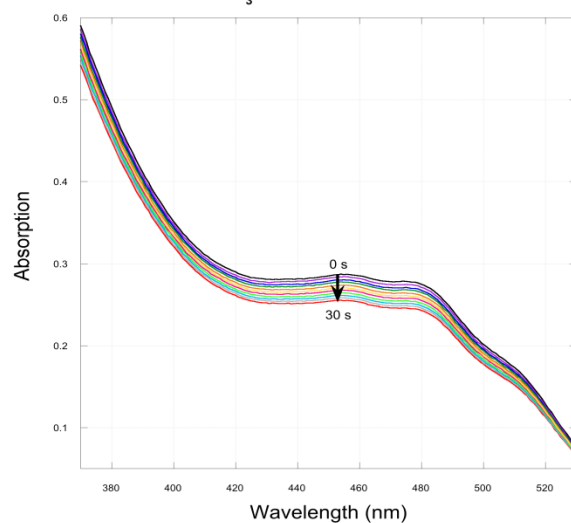
UV-Vis Spectrum for the Oxidation of $p\text{-(t-Bu)}$ Benzyl Alcohol 0 to 30s



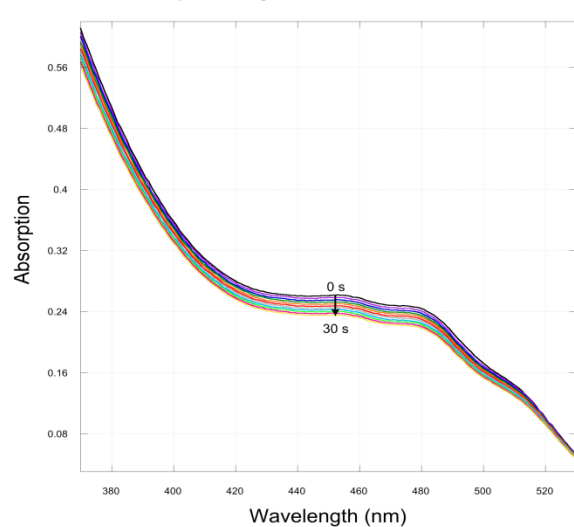
UV-Vis Spectrum for the Oxidation
of *m*-CH₃ Benzyl Alcohol 0 to 30s



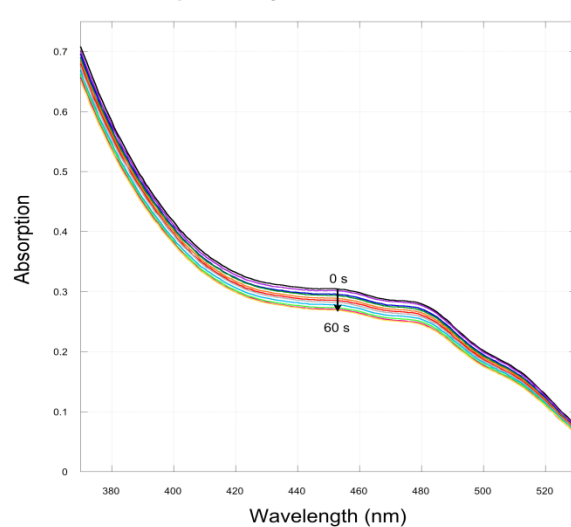
UV-Vis Spectrum for the Oxidation
of *m*-OCH₃ Benzyl Alcohol 0 to 30s



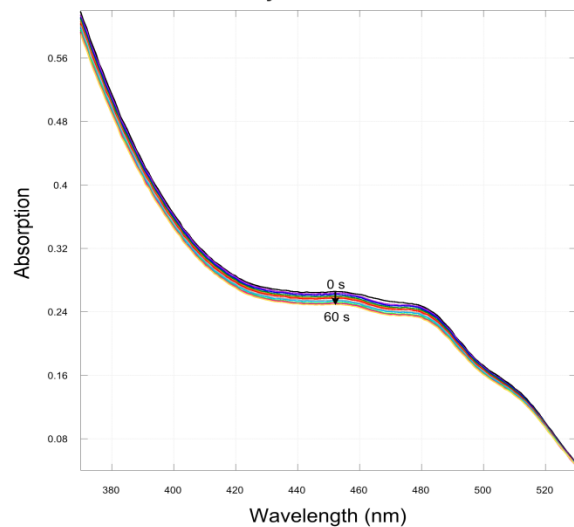
UV-Vis Spectrum for the Oxidation
of *p*-F Benzyl Alcohol 0 to 30s



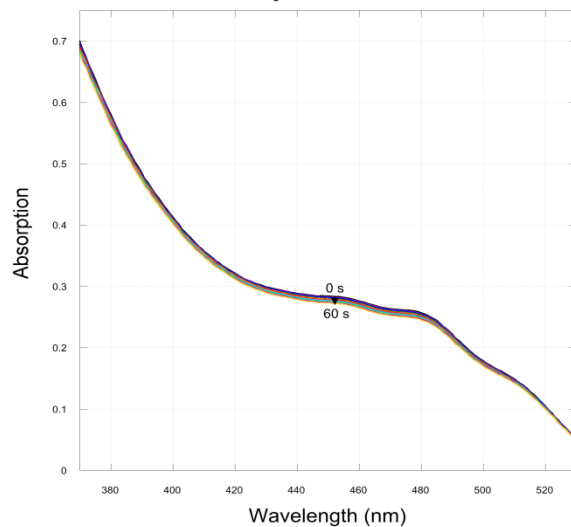
UV-Vis Spectrum for the Oxidation
of *p*-Br Benzyl Alcohol 0 to 60s



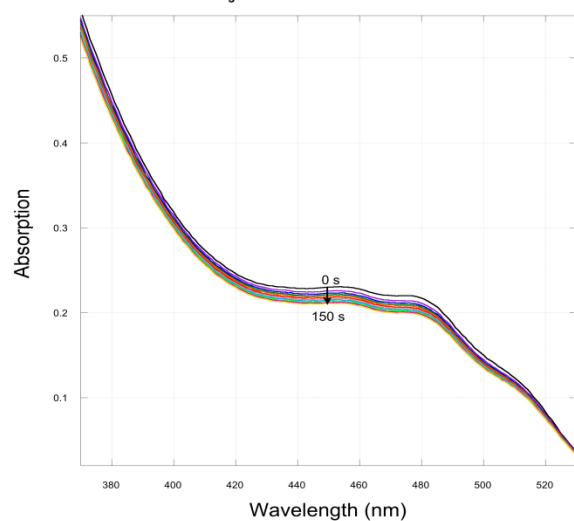
UV-Vis Spectrum for the Oxidation
of *m*-F Benzyl Alcohol 0 to 60s



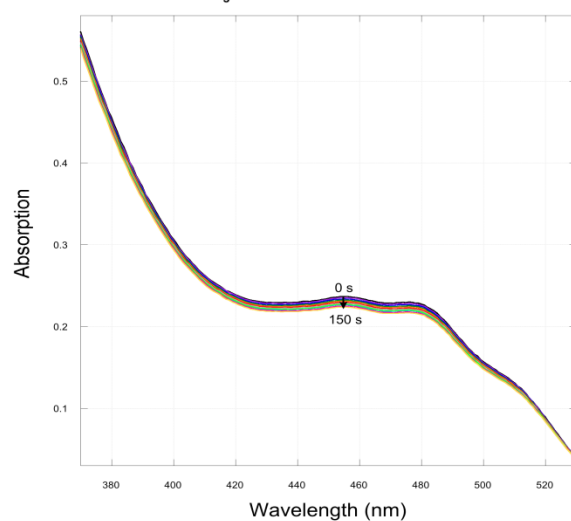
UV-Vis Spectrum for the Oxidation
of *m*-Cl Benzyl Alcohol 0 to 60s



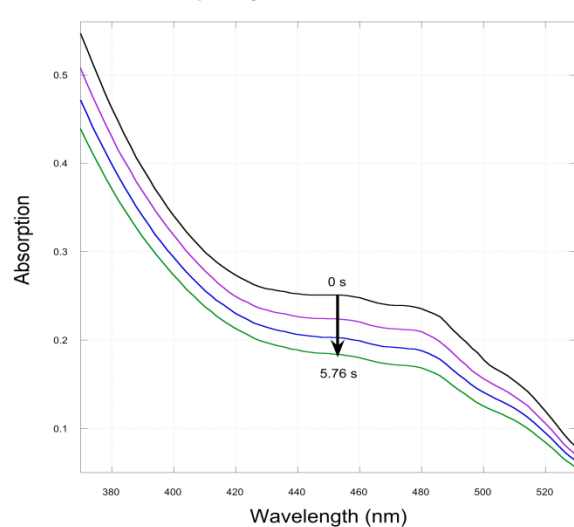
**UV-Vis Spectrum for the Oxidation
of *m*-CF₃ Benzyl Alcohol 0 to 150s**



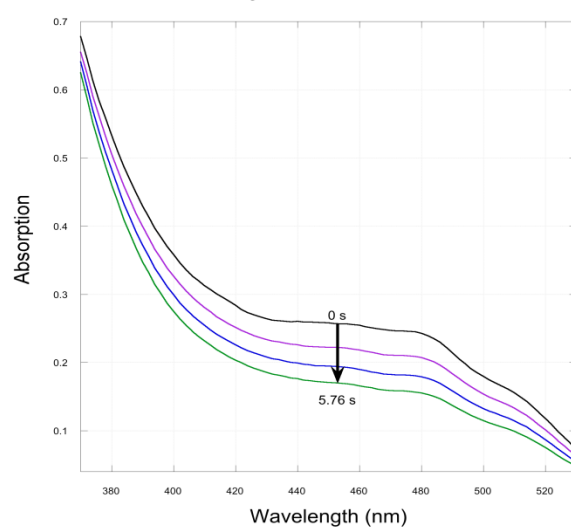
**UV-Vis Spectrum for the Oxidation
of *p*-CF₃ Benzyl Alcohol 0 to 150s**



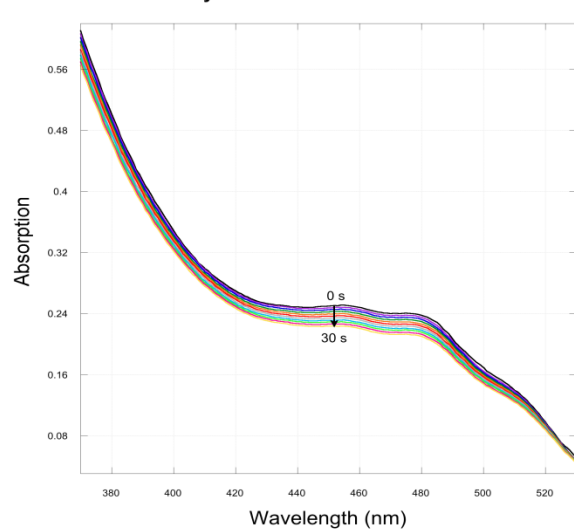
**UV-Vis Spectrum for the Oxidation
of Piperonyl Alcohol 0 to 5.76s**



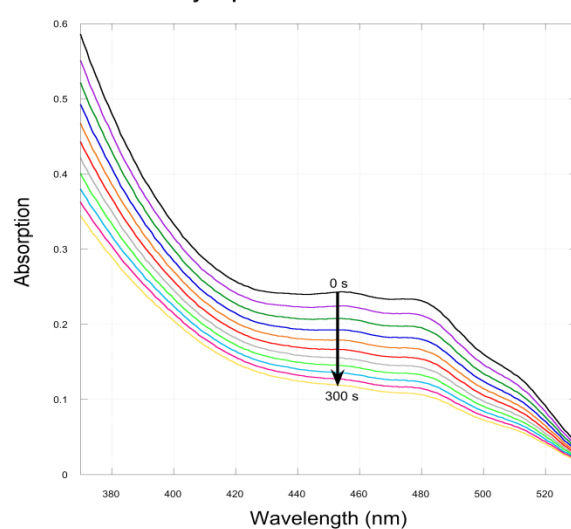
**UV-Vis Spectrum for the Oxidation
of Cinnamyl Alcohol 0 to 5.76s**



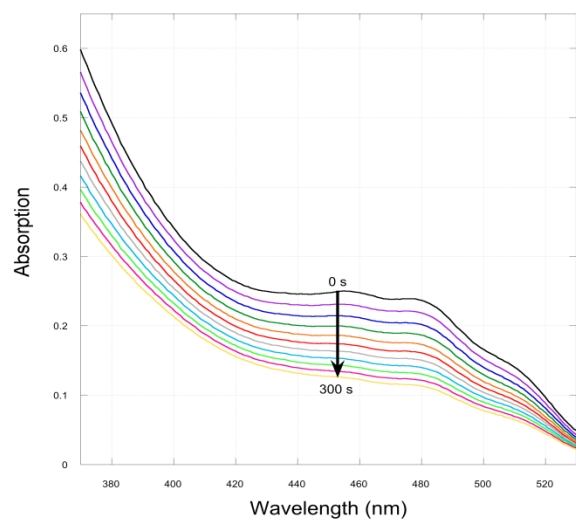
**UV-Vis Spectrum for the Oxidation
of Allyl Alcohol 0 to 30s**



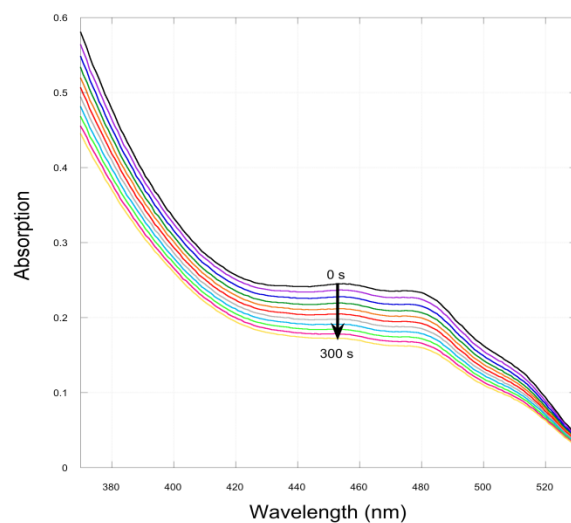
**UV-Vis Spectrum for the Oxidation
of Cyclopentanol 0 to 300s**



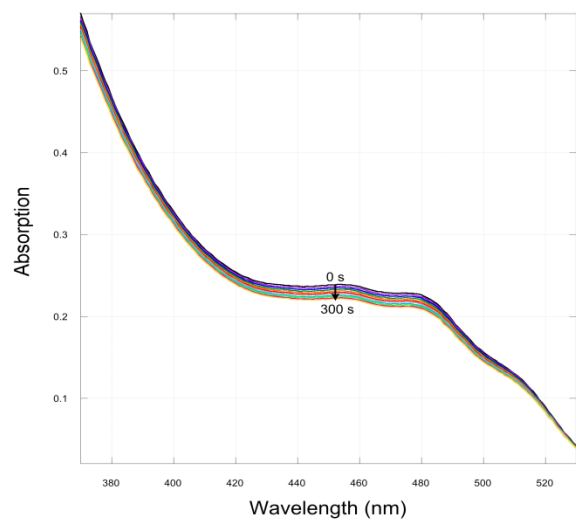
UV-Vis Spectrum for the Oxidation of Cyclohexanol 0 to 300s



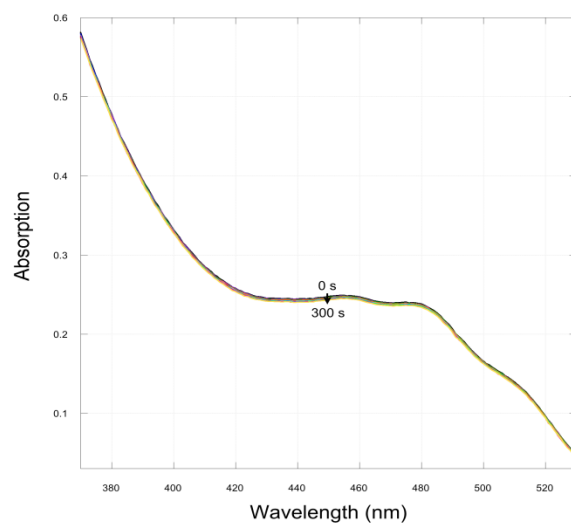
UV-Vis Spectrum for the Oxidation of 2-Hexanol 0 to 300s



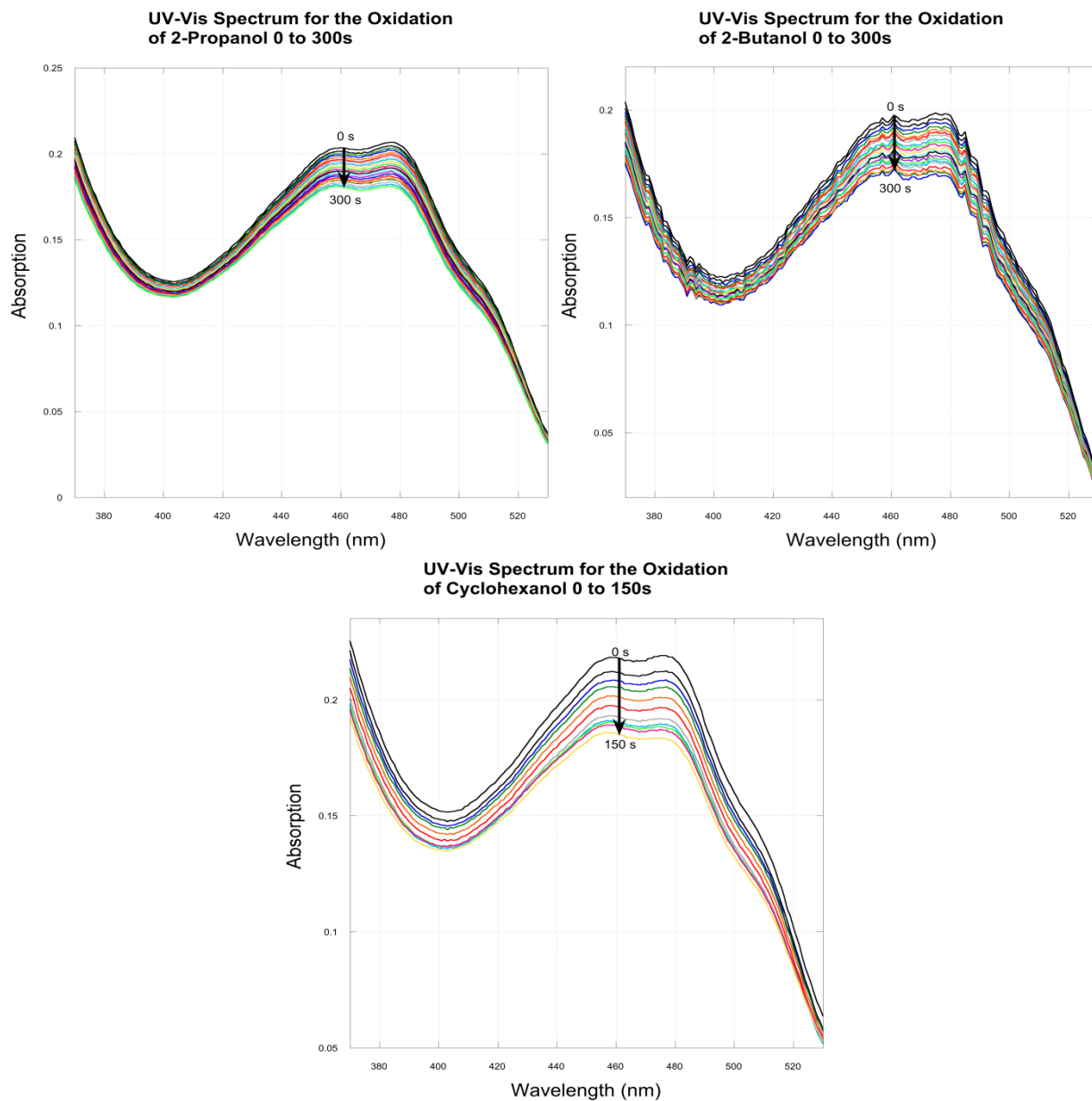
UV-Vis Spectrum for the Oxidation of 1-Heptanol 0 to 300s



UV-Vis Spectrum for the Oxidation of Neopentyl Alcohol 0 to 300s

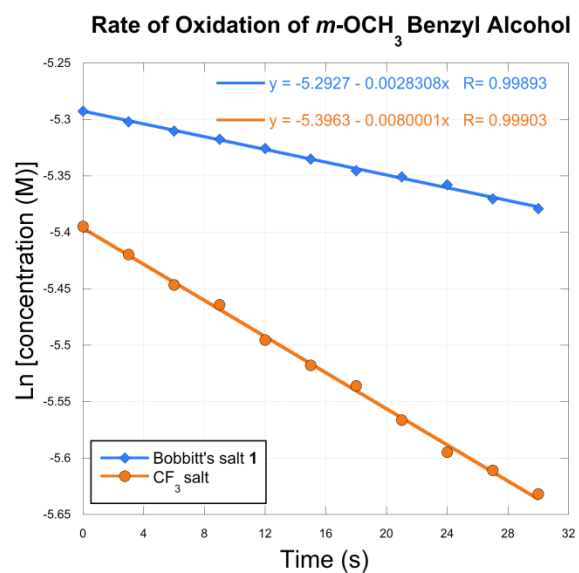
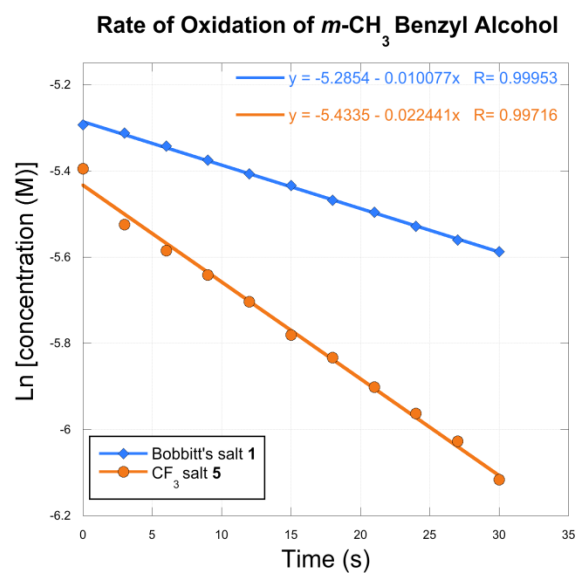
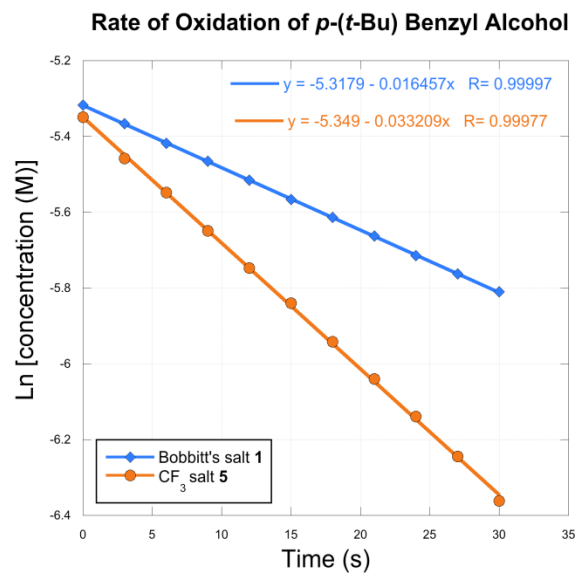
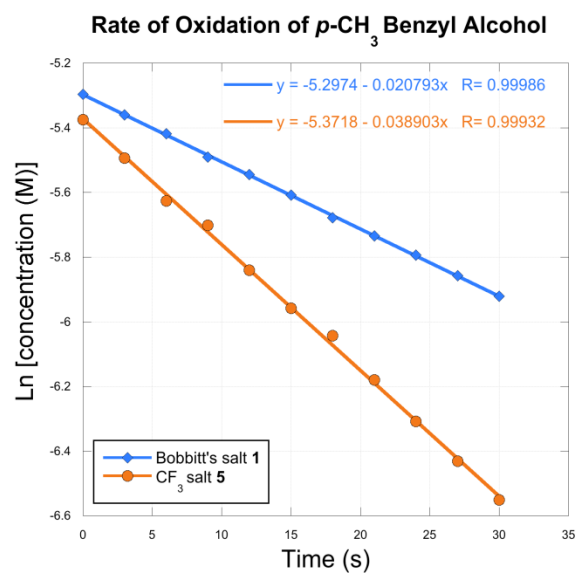
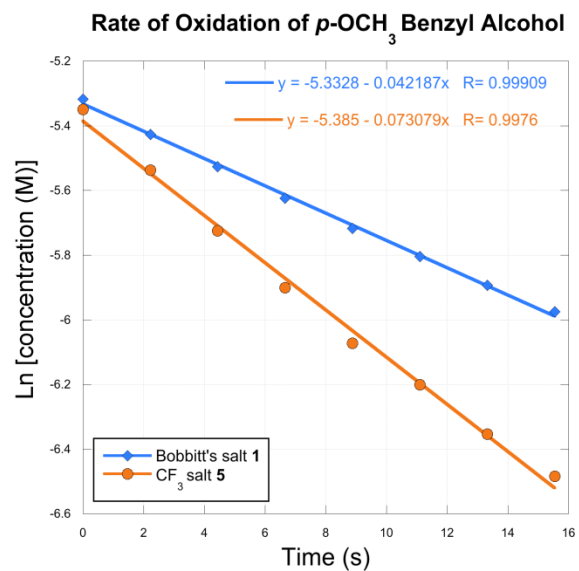
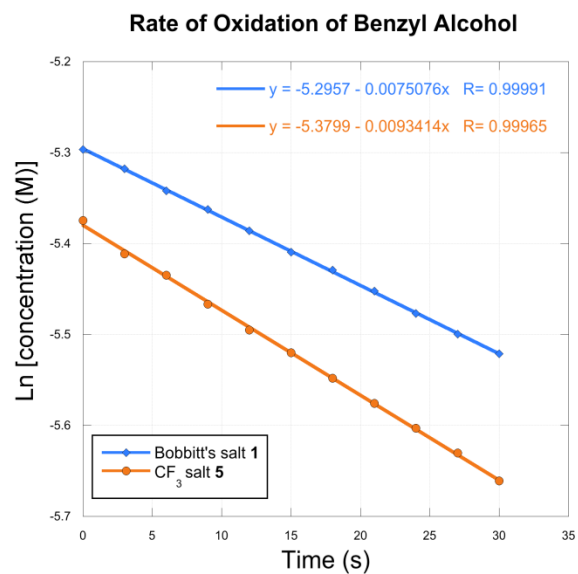


UV-Vis Spectra for Alcohol Oxidations in H₂O

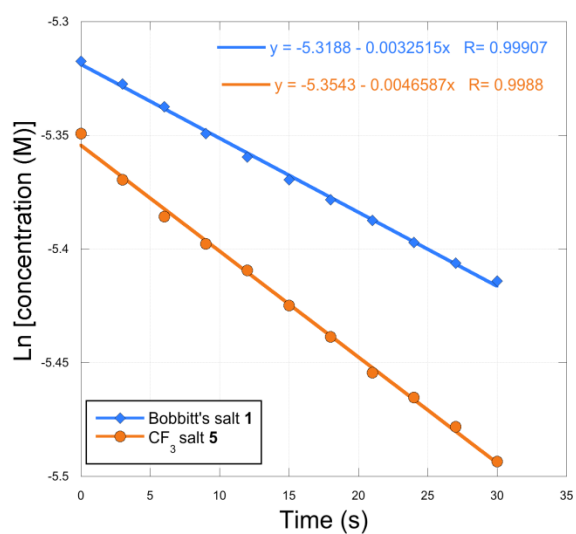


Plots of $\ln ([\text{salt}])$ vs. time (s) in CH₃CN

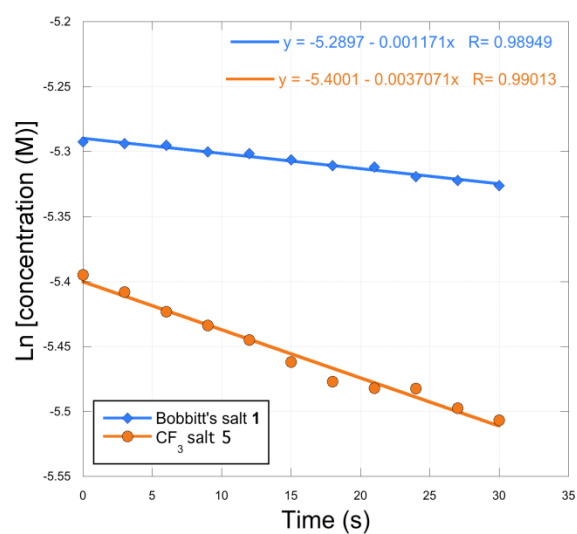
The following rate data were obtained from the UV-Vis Spectra shown above by employing the method of Harris.⁸⁵ An average of 10–11 data points were used to construct the plots, with the exception of cinnamyl and piperonyl alcohol as the rate of oxidation was so rapid, only 4 readings were able to be accurately measured.



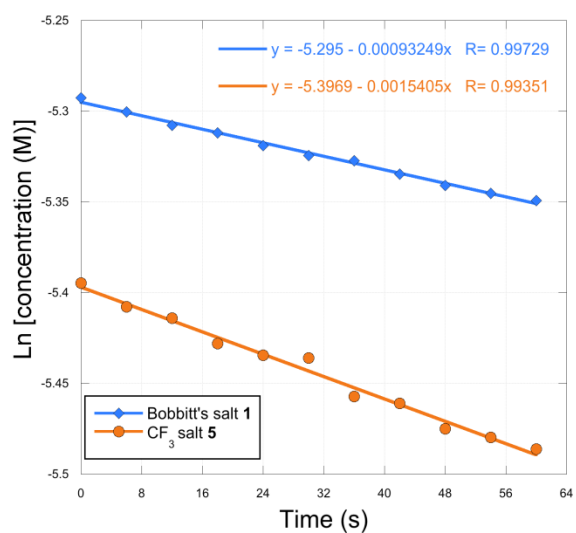
Rate of Oxidation of *p*-F Benzyl Alcohol



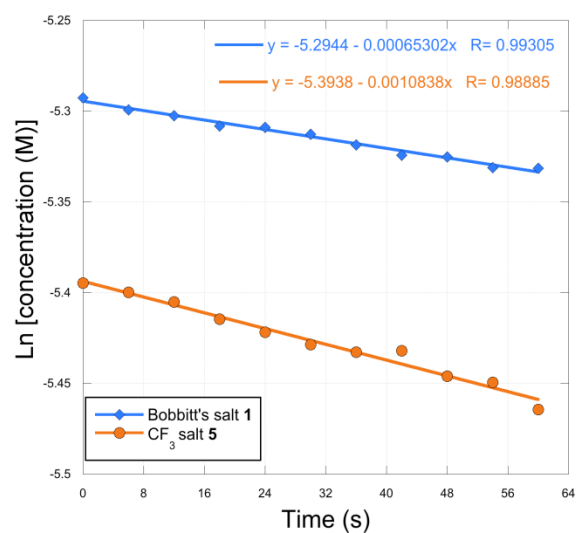
Rate of Oxidation of *p*-Br Benzyl Alcohol



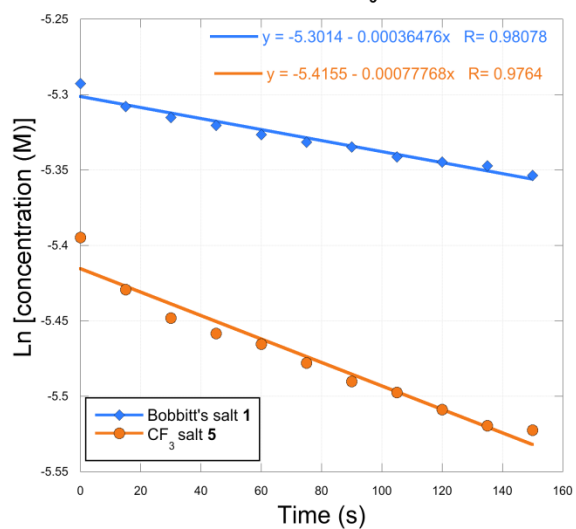
Rate of Oxidation of *m*-F Benzyl Alcohol



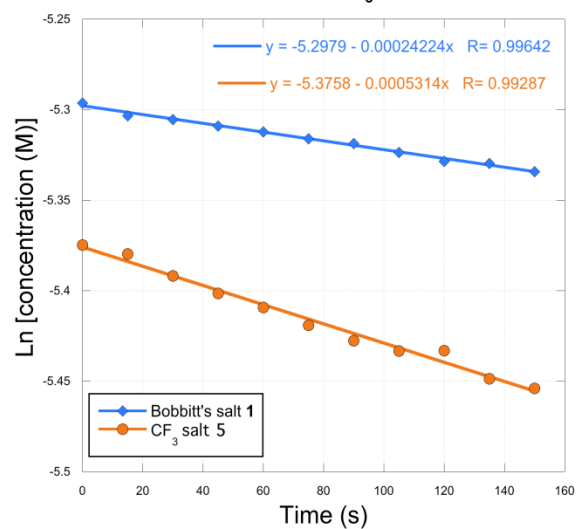
Rate of Oxidation of *m*-Cl Benzyl Alcohol

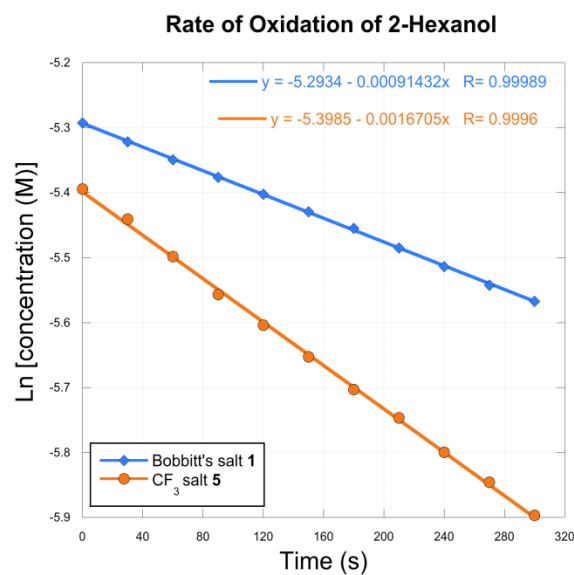
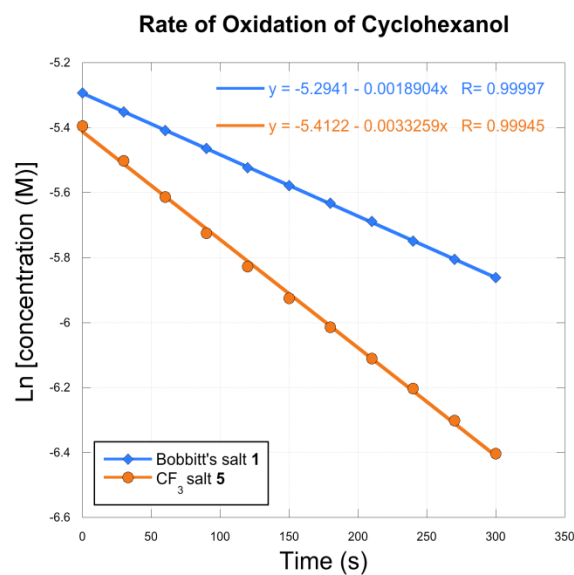
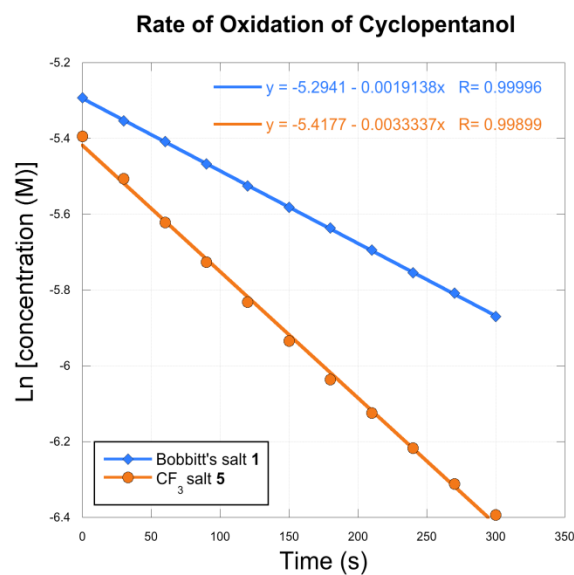
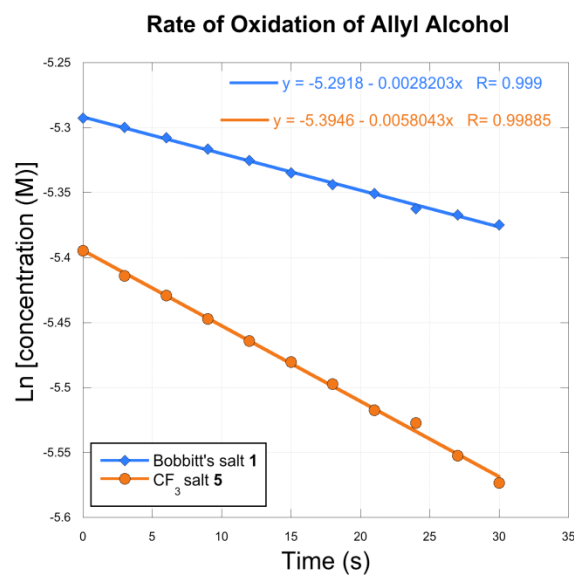
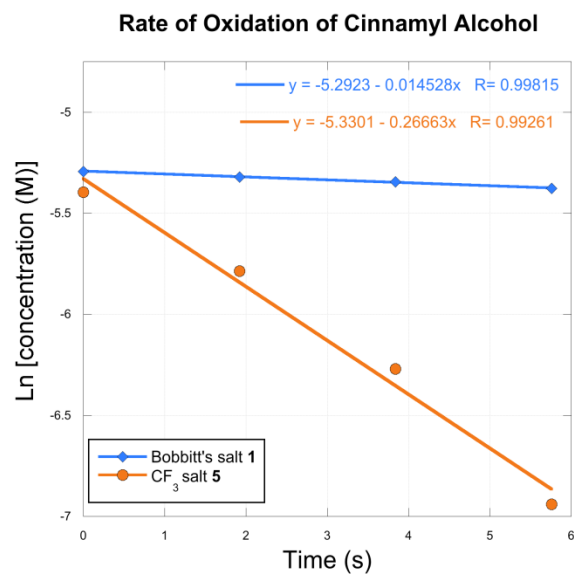
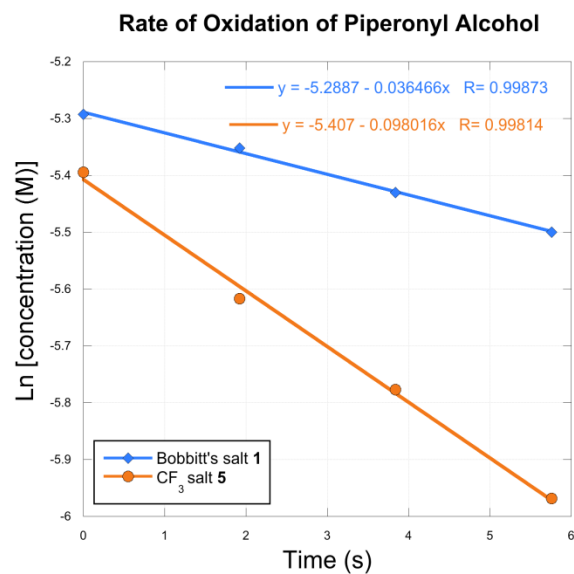


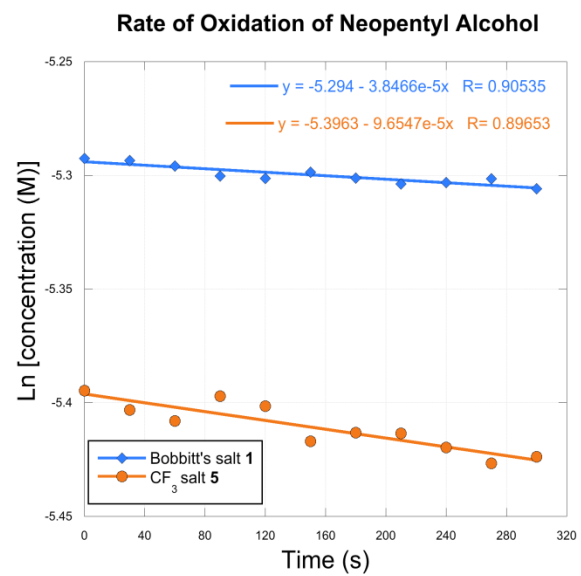
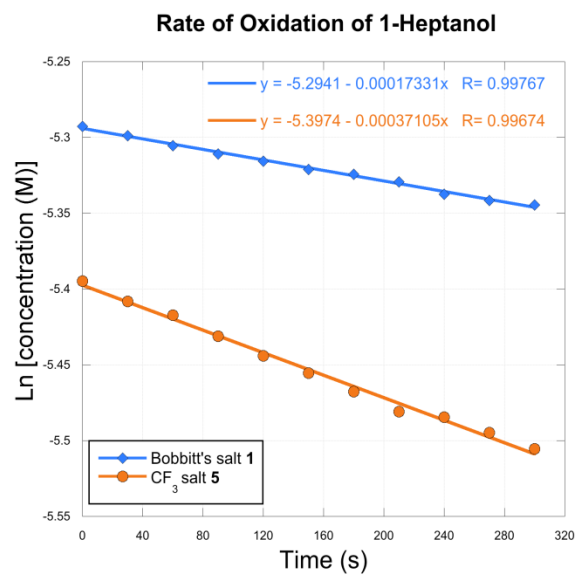
Rate of Oxidation of *m*-CF₃ Benzyl Alcohol



Rate of Oxidation of *p*-CF₃ Benzyl Alcohol

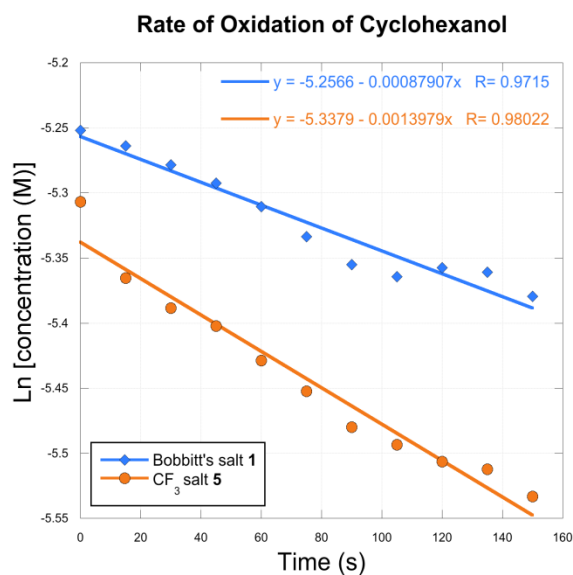
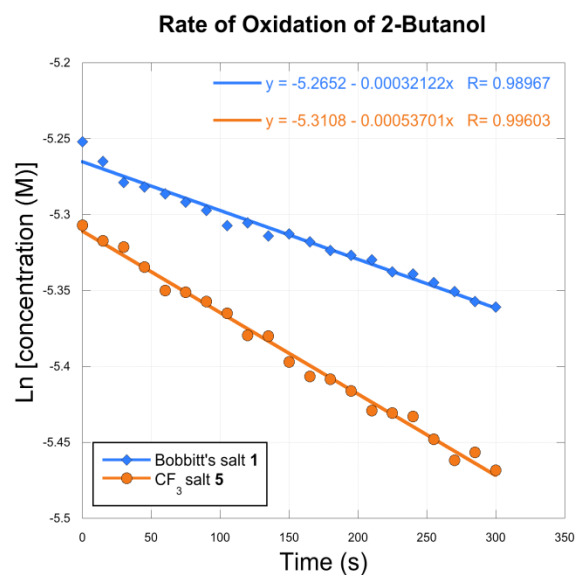
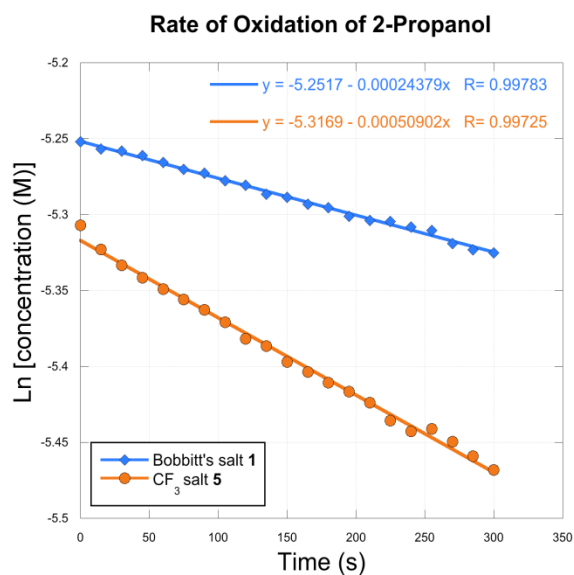




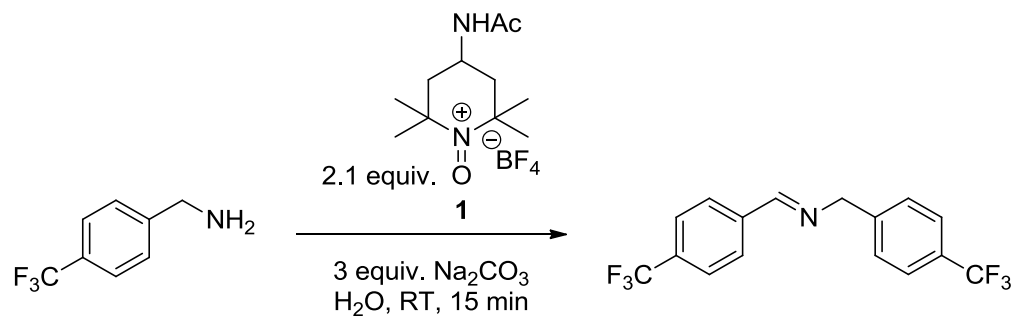


Plots of $\ln ([\text{salt}])$ vs. time (s) in H_2O

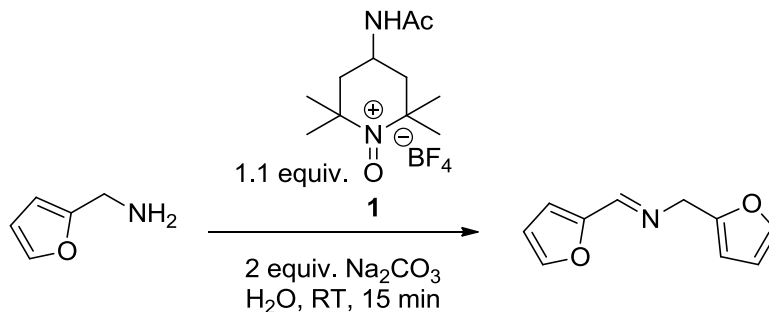
The following rate data were obtained from the UV-Vis Spectra shown above by employing the method of Harris.⁸⁵ Approximately 11–20 data points were used to construct the plots.



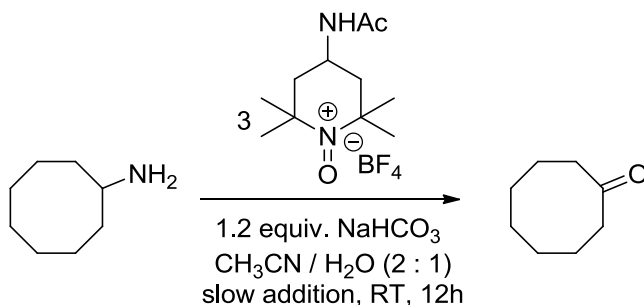
3.5 Exploration into Imine Formation with Oxoammonium Salts and Related Chemistry



(E)-N-(4-(Trifluoromethyl)benzylidene)-1-(4-(trifluoromethyl)phenyl)methanamine.⁸⁷ To a 50-mL round-bottomed flask containing a magnetic stir bar was added 1.751 g (10.0 mmol) of 4-trifluoromethylbenzylamine, 3.179 g (30.0 mmol) of Na_2CO_3 , and 20 mL of deionized water. The mixture was stirred for 2 minutes, then 6.302 g (21.0 mmol) of Bobbitt's salt (**1**) was added all at once. The nitroxide (**2**) precipitated immediately. The mixture was stirred for 15 min then 50 mL of pentane was added and the biphasic mixture was filtered through a Büchner funnel to remove the nitroxide. The filtrate was added to a separatory funnel and the organic layer was washed with two 25-mL portions of water, dried (Na_2SO_4), and solvent removed under reduced pressure to afford 1.656 g (86%) of the title compound as a clear colorless oil: ^1H NMR (400 MHz, CDCl_3) δ 4.91 (s, 2H), 7.50 (d, $J = 7.9$ Hz, 2H), 7.64 (d, $J = 7.9$ Hz, 2H), 7.71 (d, $J = 8.4$ Hz, 2H), 7.93 (d, $J = 7.9$ Hz, 2H), 8.47 (s, 1H); ^{13}C NMR (100 MHz, CDCl_3) δ 64.5, 124.2 (q, $J_{\text{C-F}} = 272.5$ Hz), 124.5 (q, $J_{\text{C-F}} = 271.4$ Hz), 125.6 (q, $J_{\text{C-F}} = 3.6$ Hz), 125.8 (q, $J_{\text{C-F}} = 3.7$ Hz), 128.3, 128.7, 129.6 (q, $J_{\text{C-F}} = 32.4$ Hz), 132.7 (q, $J_{\text{C-F}} = 32.4$ Hz), 139.3, 143.4; ^{19}F NMR (376 MHz, CDCl_3) δ -62.4 (3F), -62.8 (3F).



***N*-Furfurylidene-furfurylamine.**⁸⁷ To a 100-mL round-bottomed flask containing a magnetic stir bar was added 1.942 g (20.0 mmol) of furfurylamine, 4.239 g (40.0 mmol) of Na₂CO₃ and 40 mL of deionized water. The mixture was stirred for 2 minutes, then 6.302 g (21.0 mmol) of Bobbitt's salt (**1**) was added all at once. The nitroxide (**2**) precipitated immediately. The mixture was stirred for 15 min then 50 mL of pentane was added and the biphasic mixture was filtered through a Büchner funnel to remove the nitroxide. The filtrate was added to a separatory funnel and the organic layer was washed with two 50-mL portions of water, dried (Na₂SO₄), and solvent removed under reduced pressure to afford 1.038 g (60%) of the title compound as a clear colorless oil: ¹H NMR (400 MHz, CDCl₃) δ 4.63 (s, 2H), 6.28 (d, *J* = 3.1 Hz, 1H), 6.33 (d, *J* = 1.7 Hz, 1H), 6.46 (dd, *J* = 3.3 Hz, *J* = 1.6 Hz, 1H), 6.78 (d, *J* = 3.3 Hz, 1H), 7.38 (s, 1H) 7.50 (s, 1H), 8.11 (s, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 56.6, 124.2, 107.6, 110.2, 111.4, 114.2, 142.0, 144.6, 151.0, 151.2, 151.7.



Cyclooctanone. To a 400-mL beaker containing a stirbar was added 9.03 g (30.0 mmol) of Bobbitt's salt (**1**), 1.00 g (12.0 mmol) of NaHCO₃, and 200 mL of a 2:1 mixture of CH₃CN / H₂O. To the solution was added 1.27 g (10.0 mmol) of cyclooctylamine as a solution in 20 mL of a 2:1 mixture of CH₃CN / H₂O

via syringe pump at a rate of 20 mL / h. The reaction mixture was stirred overnight at room temperature, then diluted with 100 mL of water and transferred to a separatory funnel using 150 mL of diethyl ether to ensure complete transfer of the mixture. The aqueous layer was extracted and organic layer was removed and set aside. The aqueous layer was then further extracted with three 25-mL portions of diethyl ether. The combined organic layers were then washed with three 25-mL portions of a 10% aqueous HCl solution, three 25-mL portions of water, one 25-mL portion of brine, dried (Na_2SO_4), and solvent removed under reduced pressure to afford a light yellow oil that crystallized upon standing: mp 36–38 °C (lit.⁸⁸ 39–42 °C). GC-MS and ^1H NMR data of the crude material were fully in accord to that reported in the literature.

References for Chapter III

- ¹ Lambert, K. M.; Bobbitt, J. M.; Eldirany, S. A.; Wiberg, K. B.; Bailey, W. F. *Org. Lett.* **2014**, *16*, 6484–64
- ² Gaussian 09, Revision A.02, Frisch, M. J.; Trucks, G. W.; Schlegel, H. B.; Scuseria, G. E.; Robb, M. A.; Cheeseman, J. R.; Scalmani, G.; Barone, V.; Mennucci, B.; Petersson, G. A.; Nakatsuji, H.; Caricato, M.; Li, X.; Hratchian, H. P.; Izmaylov, A. F.; Bloino, J.; Zheng, G.; Sonnenberg, J. L.; Hada, M.; Ehara, M.; Toyota, K.; Fukuda, R.; Hasegawa, J.; Ishida, M.; Nakajima, T.; Honda, Y.; Kitao, O.; Nakai, H.; Vreven, T.; Montgomery, J. A., Jr.; Peralta, J. E.; Ogliaro, F.; Bearpark, M.; Heyd, J. J.; Brothers, E.; Kudin, K. N.; Staroverov, V. N.; Kobayashi, R.; Normand, J.; Raghavachari, K.; Rendell, A.; Burant, J. C.; Iyengar, S. S.; Tomasi, J.; Cossi, M.; Rega, N.; Millam, N. J.; Klene, M.; Knox, J. E.; Cross, J. B.; Bakken, V.; Adamo, C.; Jaramillo, J.; Gomperts, R.; Stratmann, R. E.; Yazyev, O.; Austin, A. J.; Cammi, R.; Pomelli, C.; Ochterski, J. W.; Martin, R. L.; Morokuma, K.; Zakrzewski, V. G.; Voth, G. A.; Salvador, P.; Dannenberg, J. J.; Dapprich, S.; Daniels, A. D.; Farkas, Ö.; Foresman, J. B.; Ortiz, J. V.; Cioslowski, J.; Fox, D. J. Gaussian, Inc., Wallingford CT, **2009**.
- ³ Legault, C. Y, Université de Sherbrook, 2009. (<http://www.cylvview.org>).
- ⁴ Moody, C.J.; Rahimtoola, K.F. *J. Org. Chem.* **1992**, *57*, 2105–2114.
- ⁵ Mercadante, M. A.; Kelly, C. B.; Bobbitt, J. M.; Tilley, L. J.; Leadbeater, N. E. *Nat. Protoc.* **2013**, *8*, 666–676.
- ⁶ Kahlbaum, G.W.A.; von Wirkner, C.G. *Chem. Ber.* **1894**, *27*, 1894.
- ⁷ Rokade, B.V.; Prabhu, K.R. *J. Org. Chem.* **2012**, *77*, 5364.
- ⁸ Ushijima, S.; Moriyama, H.T.; *Tetrahedron* **2011**, *67*, 958.
- ⁹ Katzman, S.M.; Moffat, J. J. *J. Org. Chem.* **1972**, *37*, 1842.
- ¹⁰ Ackermann, L.; Potukuchi, H.K.; Althammer, A.; Born, R.; Mayer, P. *Org. Lett.* **2010**, *12*, 1004.
- ¹¹ Cheung, C.W.; Buchwald, S.L. *J. Org. Chem.* **2014**, *79*, 5351.
- ¹² Ye, Y.; Schimler, S.D.; Hanley, P.S.; Sanford, M.S. *J. Am. Chem. Soc.* **2013**, *135*, 16292.
- ¹³ Taft, R.W.; Price, E.; Fox, I.R.; Lewis, I.C.; Andersen, K.K.; David, G.T. *J. Am. Chem. Soc.* **1963**, *85*, 3146.
- ¹⁴ Bernstein, J.; Yale, H.L.; Losee, K.; Holsing, M.; Martins, J.; Lott, W.A. *J. Am. Chem. Soc.* **1951**, *73*, 906.
- ¹⁵ Knauber, T.; Arikian, F.; Röschenthaler, G.-V.; Gooßen, L. J. *Chem. Eur. J.* **2011**, *17*, 2689.
- ¹⁶ Christau, H.; Ouali, A.; Spindler, J. *Chem. Eur.* **2005**, *11*, 2483.
- ¹⁷ Schareina, T.; Zapf, A.; Mägerlein, W.; Müller, N. and Beller, M. *Chem. Eur. J.*, **2007**, *13*, 6249.
- ¹⁸ Norris, J.F.; Klemka, A.J. *J. Am. Chem. Soc.* **1940**, *62*, 1432.
- ¹⁹ Du, B.; Jiang, X.; Sun, P. *J. Org. Chem.* **2013**, *78*, 2786.
- ²⁰ Laulhé, S.; Gori, S.S.; Nantz, M.H. *J. Org. Chem.* **2012**, *77*, 9334.
- ²¹ Cantillo, D.; Kappe, C.O. *J. Org. Chem.* **2013**, *78*, 10567.
- ²² Xiao, Z.; Timberlake, J.W. *Tetrahedron* **1998**, *54*, 12715.
- ²³ Lambert, K. M.; Bobbitt, J. M.; Eldirany, S. A.; Kissane, L. E.; Sheridan, R. K.; Stempel, Z. D.; Sternberg, F. H.; Bailey, W. F. *Chem. Eur. J.* **2016**, *22*, 5156–5159.
- ²⁴ Farcasiu, D.; Jahme, J.; Ruchardt, C. *J. Am. Chem. Soc.* **1985**, *107*, 5717.
- ²⁵ Ferris, A.; Johnson, G.; Gould, F. *J. Org. Chem.* **1960**, *25*, 1813.
- ²⁶ Senecal, T. D.; Shu, W.; Buchwald, S. L. *Angew. Chem. Int. Ed.* **2013**, *52*, 10035.
- ²⁷ Castagnetti, E.; Schlosser, M. *Eur. J. Org. Chem.* **2001**, *4*, 691.
- ²⁸ Suzuki, Y.; Moriyama, K.; Togo, H. *Tetrahedron*. **2011**, *67*, 7956.
- ²⁹ Herbst, R. M.; Wilson, K. R. *J. Org. Chem.* **1957**, *22*, 1142.
- ³⁰ Asano, K.; Matsubara, S. *Heterocycles* **2010**, *80*, 989.
- ³¹ Balderman, D.; Kalir, A. *Synthesis*. **1978**, *1*, 24.
- ³² Goebel, H. L.; Wenzke, H. H. *J. Am. Chem. Soc.* **1938**, *60*, 697.
- ³³ Meltzer, R. I.; Lewis, A. D.; King, J. A. *J. Am. Chem. Soc.* **1955**, *77*, 4062.
- ³⁴ Grignard, V.; Bellet, F.; Courtot, C. *Ann. Chim. (Paris, Fr.)* **1919**, *9*, 382.
- ³⁵ Stevens, C. L.; Coffield, T. H. *J. Am. Chem. Soc.* **1951**, *73*, 103.
- ³⁶ Merckx, R.; Verhulst, J.; Bruylants, P. *Bull. Soc. Chim. Belg.* **1933**, *42*, 182.
- ³⁷ Veitch, G. E.; Bridgwood, K. L.; Ley, S. V. *Org. Lett.* **2008**, *10*, 3623.
- ³⁸ Tsarev, V. N.; Morioka, Y.; Caner, J.; Wang, Q.; Ushimaru, R.; Kudo, A.; Naka, H.; Saito, S. *Org. Lett.* **2015**, *17*, 2530.
- ³⁹ Soerensen, J. S.; Soerensen, N. A. *Acta Chem. Scand.* **1948**, *2*, 166.
- ⁴⁰ Aleksandrova, E. K. *Russ. J. Org. Chem.* **1973**, *9*, 756.
- ⁴¹ Shvekhgeimer, G. A.; Kuz'micheva, L.K.; Novikov, S.S. *Russ. Chem. Bull.* **1974**, *23*, 134.
- ⁴² Klimko, Y. E.; Isaev, S. D.; Yurchenko, A. G. *Russ. J. Org. Chem.* **1994**, *30*, 1776.

- ⁴³ Boehme, H.; Neidlein, R. *Chem. Ber.* **1962**, *95*, 1859.
- ⁴⁴ Kim, J.; Choi, J.; Shin, K.; Chang, S. *J. Am. Chem. Soc.* **2012**, *134*, 2528.
- ⁴⁵ Padwa, A.; Rashatasakhon, P.; Ozdemir, A. D.; Willis, J. *J. Org. Chem.* **2005**, *70*, 519.
- ⁴⁶ White, J. D.; Blakemore, P. R.; Browder, C. C.; Hong, J.; Lincoln, C. M.; Nargornyy, P. A.; Robarge, L. A.; Wardrop, D. J. *J. Am. Chem. Soc.* **2001**, *123*, 8593.
- ⁴⁷ Mueller, E.; Huber, H. *Chem. Ber.* **1963**, *96*, 2319.
- ⁴⁸ Korosi, G.; Kovats, E. S. *J. Chem. Eng. Data* **1981**, *26*, 323–332.
- ⁴⁹ Suzuki, Y.; Yoshino, T.; Moriyama, K.; Togo, H. *Tetrahedron*, **2011**, *67*, 3809–3814.
- ⁵⁰ Kelly, C. B.; Lambert, K. M.; Mercadante, M. A.; Ovian, J. M.; Bailey, W. F.; Leadbeater, N. E. *Angew. Chem. Int. Ed.* **2015**, *127*, 4315–4319.
- ⁵¹ Ravikumar, I.; Saha, S.; Ghosh, P. *Chem. Commun.* **2011**, *47*, 4721.
- ⁵² For complete details on the synthesis of the starting aldehyde substrates see the Supporting Information for ref. 50.
- ⁵³ Interestingly, upon addition of the salt **1** the solution became a vivid green color which quickly faded and the solution became yellow. The origin of the green color is unknown, but it appears to be unique to very electron rich aryl systems. The lifetime of the green coloration can be enhanced by cooling to 0 °C although it is unknown why this occurs.
- ⁵⁴ While on small scales the reaction does not require cooling, it is advisable that a room temperature water bath be employed upon scale-up as the reaction is mildly exothermic.
- ⁵⁵ In some cases, the material obtained after rotary evaporation contained trace impurities resulting from decomposition of **1** or residual aldehyde. To remove the impurities resulting from **1**, a silica gel plug was run in the fashion outlined in this experimental; details are provided where applicable. To remove residual aldehyde, a commercially available scavenger *Silabond® Amine* available from Silicycle Inc. was utilized.
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- ⁵⁹ Tsuchiya, D.; Kawagoe, Y.; Moriyama, K.; Togo, H. *Org. Lett.*, **2013**, *15*, 4194.
- ⁶⁰ Wang, Z.; Chang, S. *Org. Lett.*, **2013**, *15*, 1990.
- ⁶¹ Dornan, L. M.; Cao, Q.; Flanagan, J. C. A.; Crawford, J. J.; Cook, M. J.; Muldoon, M. J. *Chem. Commun.* **2013**, *49*, 6030.
- ⁶² Zhang, Z.; Liebeskind, L. S. *Org. Lett.*, **2006**, *8*, 4331.
- ⁶³ Grigg, R.; Knight, J. A.; Sargent, M. V. *J. Chem. Soc.* **1965**, 6057.
- ⁶⁴ Yasuda, T.; Shimizu, T.; Liu, F.; Ungar, G.; Kato, T. *J. Am. Chem. Soc.*, **2011**, *133*, 13437.
- ⁶⁵ Kim, J.; Kim, H.; Chang, S. *Org. Lett.* **2012**, *14*, 3924.
- ⁶⁶ This compound can be easily recrystallized from CHCl₃:Et₂O
- ⁶⁷ Anxionnat, B.; Pardo, D. G.; Ricci, G.; Rossen, K.; Cossy, J. *Org. Lett.*, **2013**, *15*, 3876.
- ⁶⁸ Hanada, S.; Motoyama, Y.; Nagashima, H. *Eur. J. Org. Chem.* **2008**, 4097.
- ⁶⁹ Miyagi, K.; Moriyama, K.; Togo, H. *Eur. J. Org. Chem.* **2013**, 5886.
- ⁷⁰ Lerebours, R.; Wolf, C. *Org. Lett.* **2007**, *9*, 2737.
- ⁷¹ Okimoto, M.; Chiba, T. *J. Org. Chem.* **1990**, *55*, 1070.
- ⁷² Fleming, F. F.; Zhang, Z.; Liu, W.; Knochel, P. *J. Org. Chem.* **2005**, *70*, 2200.
- ⁷³ This compound can easily be recrystallized from pentane
- ⁷⁴ Rokade, B. V.; Malekar, S. K.; Prabhu, K. R. *Chem. Commun.* **2012**, *48*, 5506.
- ⁷⁵ Wang, T.; Yin, H.; Jiao, N. *Adv. Synth. Catal.* **2013**, *355*, 1207.
- ⁷⁶ Ramachandran, P. V. and Burghardt, T. E. *Chem. Eur. J.* **2005**, *11*, 4387.
- ⁷⁷ Hart, D. J.; Kanai, K.; Thomas, D. G.; Yang, T. *J. Org. Chem.* **1983**, *48*, 289.
- ⁷⁸ Yu, L.; Li, H.; Zhang, X.; Ye, J.; Liu, J.; Xu, Q.; Lautens, M. *Org. Lett.*, **2014**, *16*, 1346.

⁷⁹ Presumably, the aldehyde results from partial hydrolysis under the reaction conditions as the solvent, pyridine, and the oxoammonium salt **1** were not rigorously dried prior to oxidation. This is consistent with the findings of Ref.

⁸⁰ The spectrophotometer used was a Cary 60 from Agilent Technologies (version 2.00) scanning from 550–350 nm at a rate of 4600 or 9600 nm/min.

⁸¹ The baseline was corrected to account for any residual absorbance from the acetonitrile solvent by running a blank with the dry acetonitrile solvent before initiating the oxidation.

⁸² Cinnamyl was the fastest oxidized substrate investigated with a half-time of 2.60 s with **5**. Whereas, neopentyl alcohol was the slowest oxidized substrate tested with a half-time of 2.00 h with **5**.

⁸³ Pirwitz, J.; Damerau, W. *Z. Chem.* **1976**, *16*, 401–402.

⁸⁴ Failure to add the sodium carbonate in portions and maintain a pH < 9 results in partial hydrolysis of the amide

⁸⁵ The crude nitroxide is sufficient for most purposes as it is used as a catalyst and the trace inorganic impurities (sodium carbonate and sodium bicarbonate) are removed upon recrystallization of the oxoammonium salt in the next step. In cases where pure analytical quality nitroxide is required, it should be recrystallized.

⁸⁶ The title compound was powdered with a mortar and pestle and stored under argon in a plastic bottle.

⁸⁷ Wendlandt, A. E.; Stahl, S. S. *Org. Lett.* **2012**, *14*, 2850–2853.

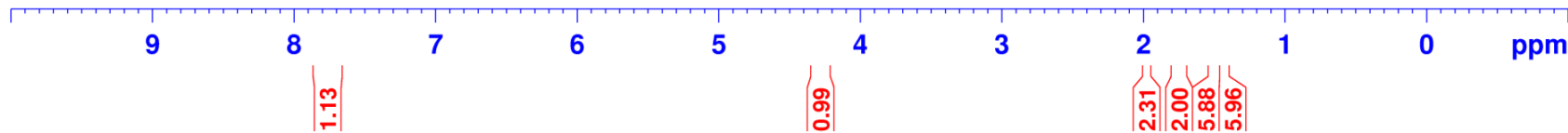
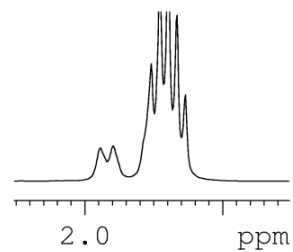
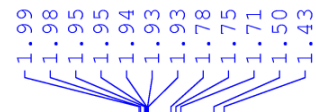
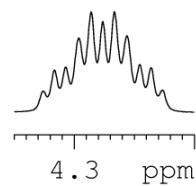
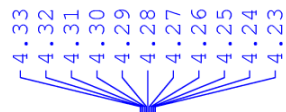
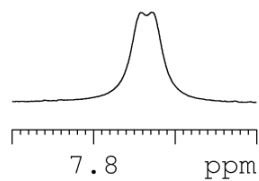
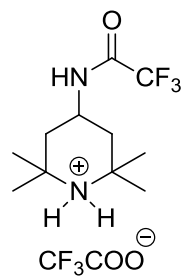
⁸⁸ Brown, H. C.; Zaidlewicz, M. *J. Am. Chem. Soc.* **1976**, *98*, 4917–4925.



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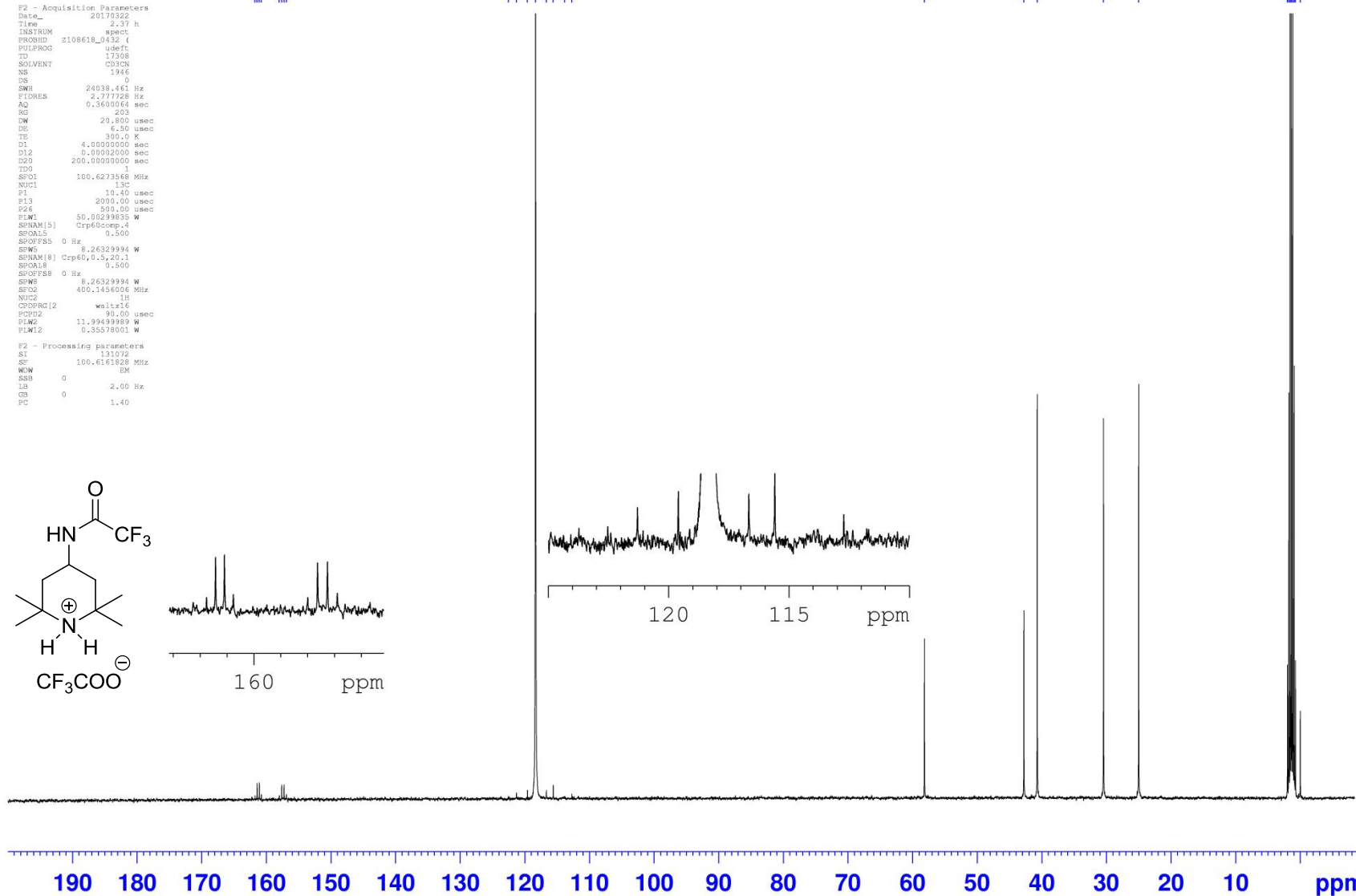
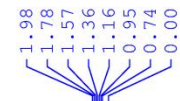
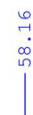
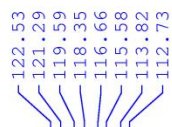
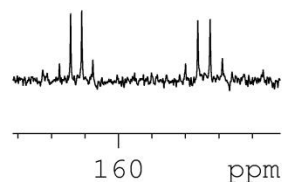
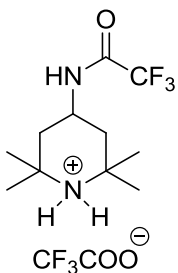


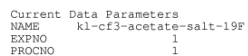


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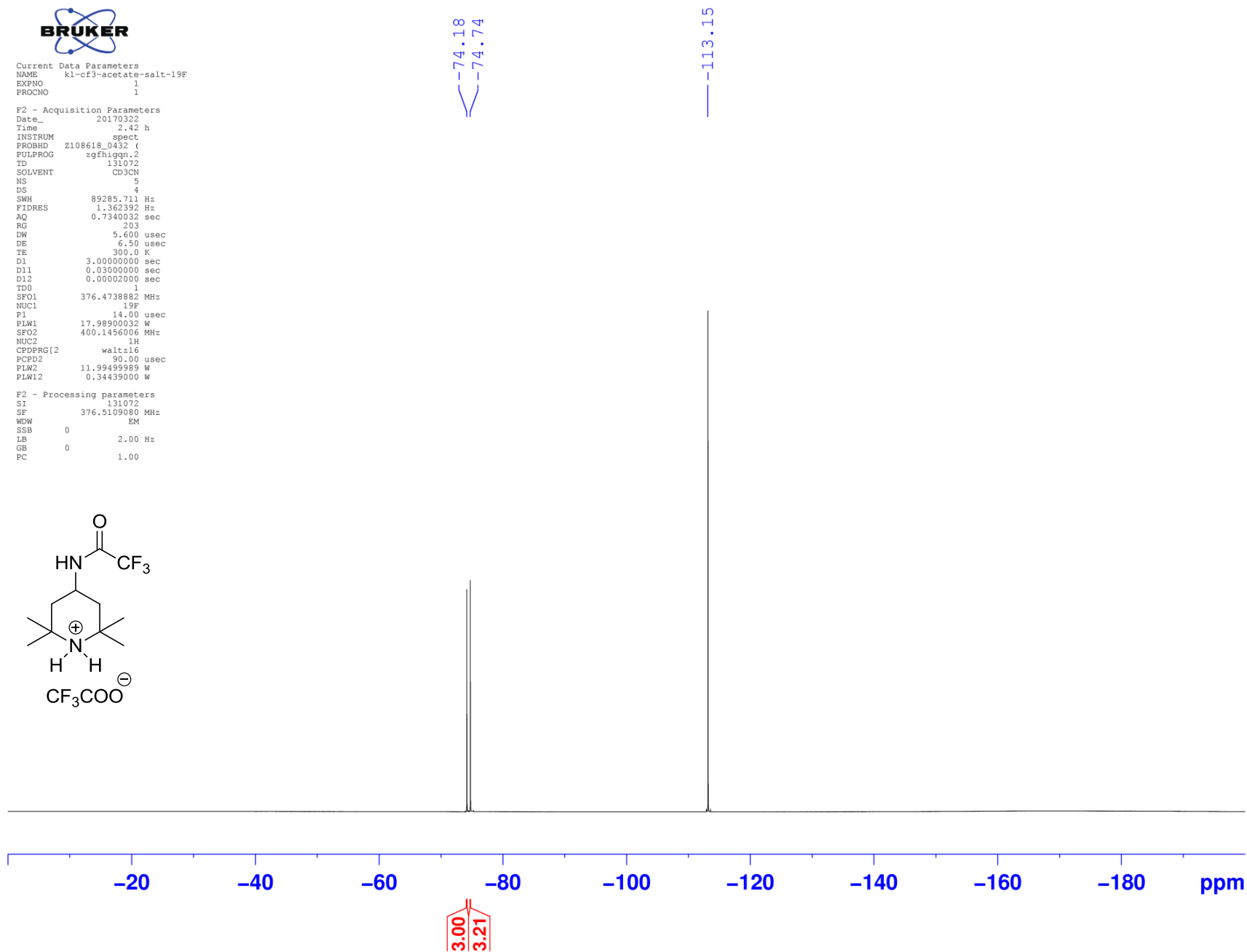
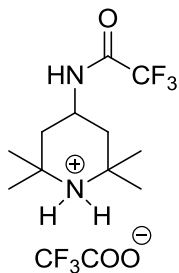


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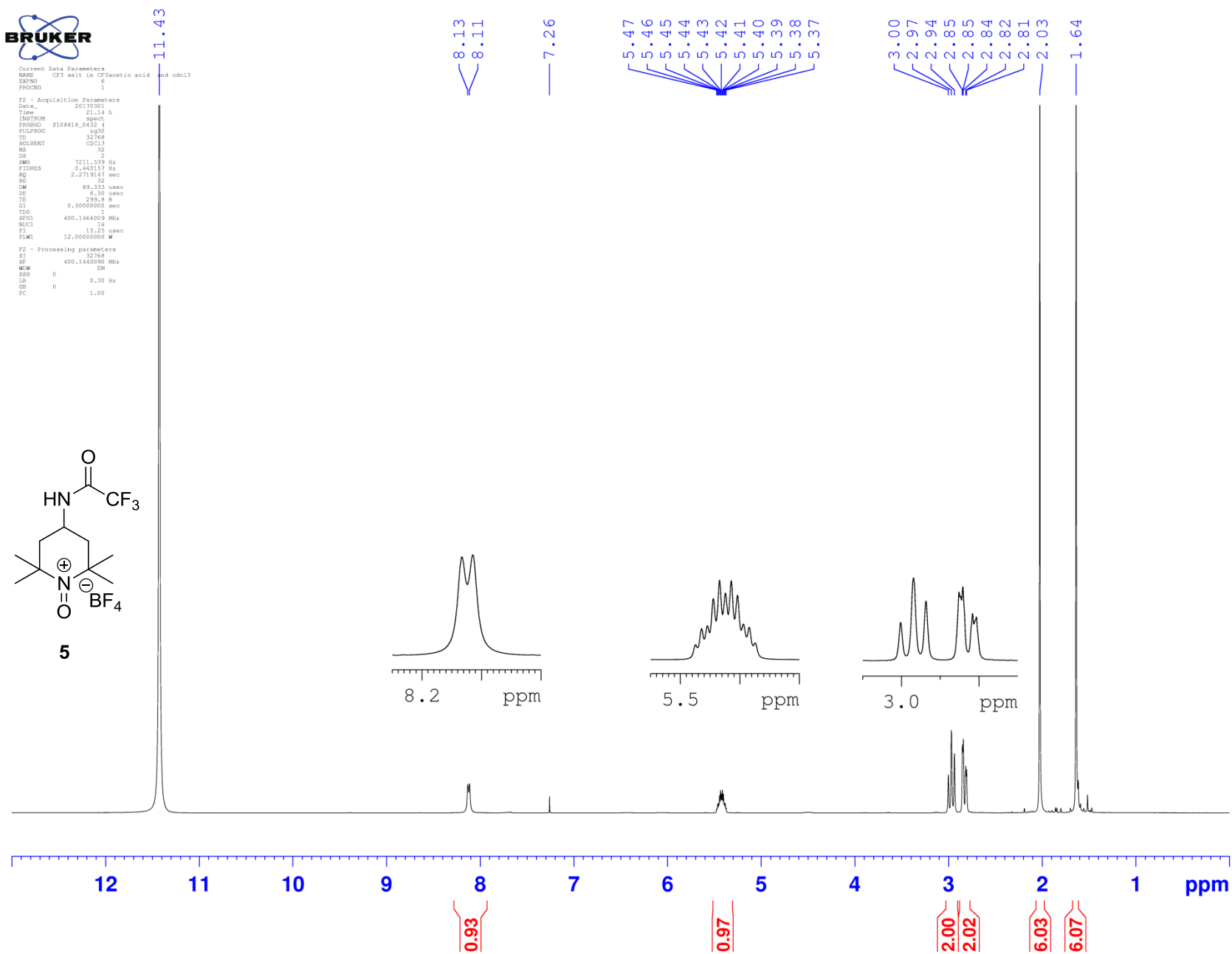
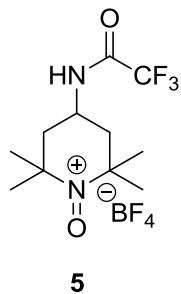
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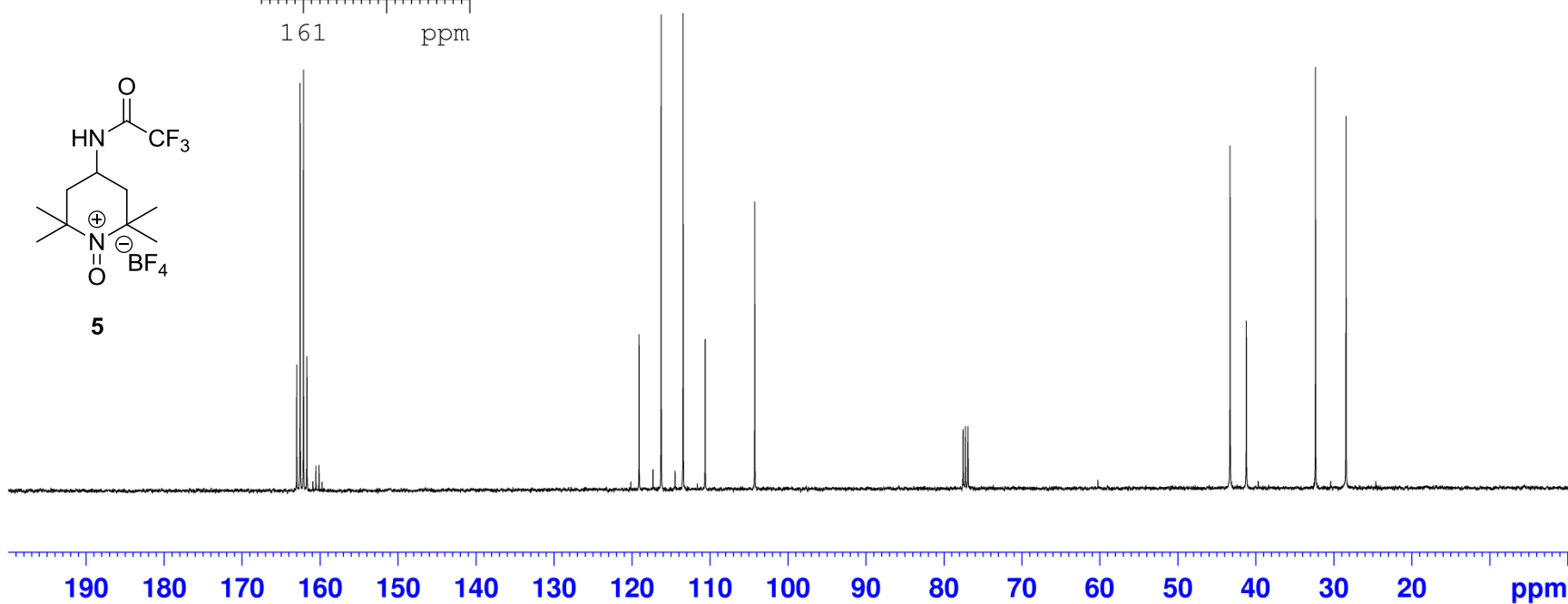
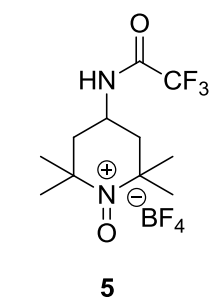
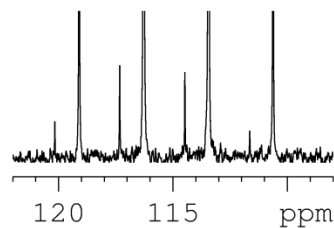
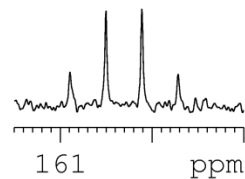
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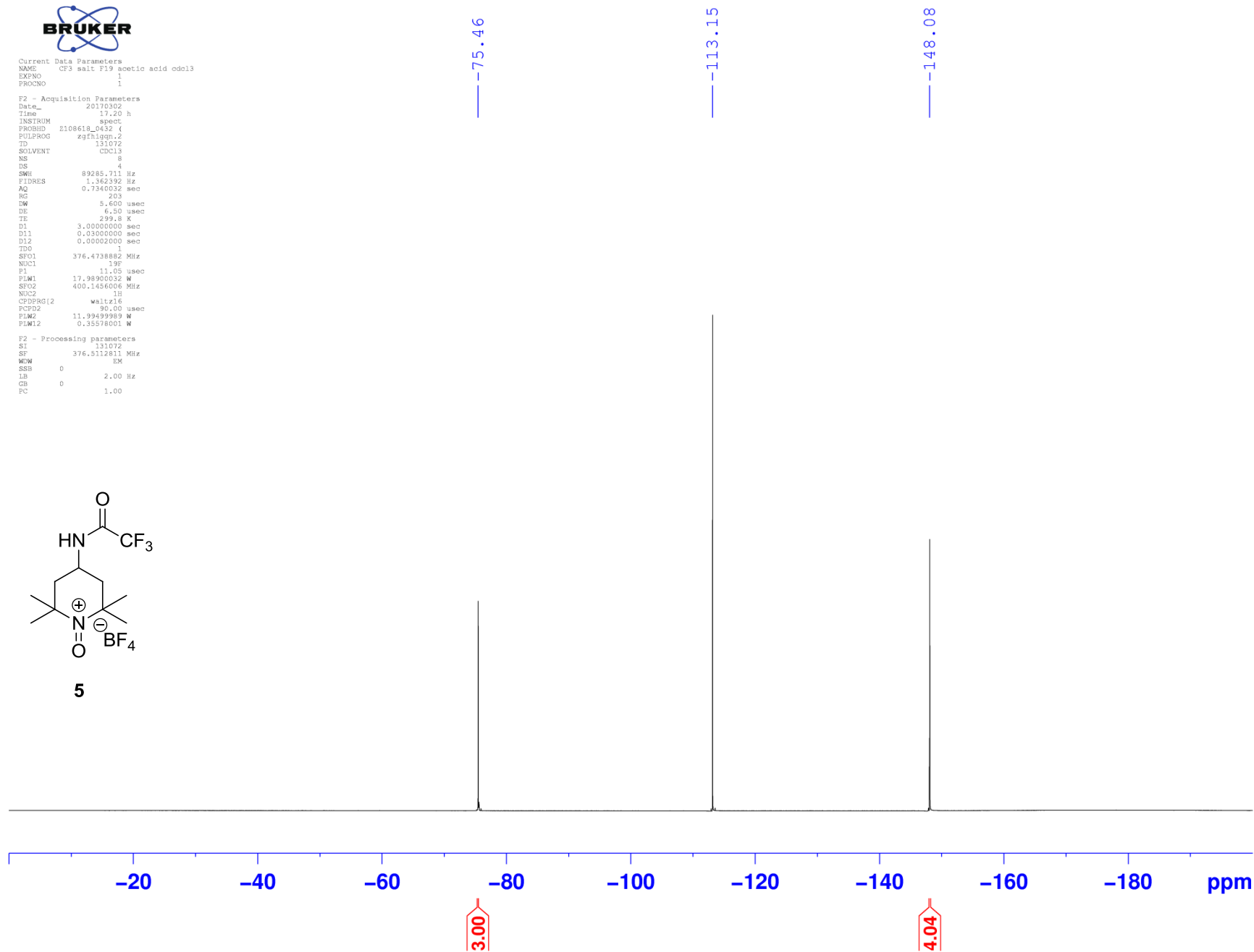
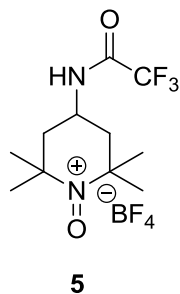


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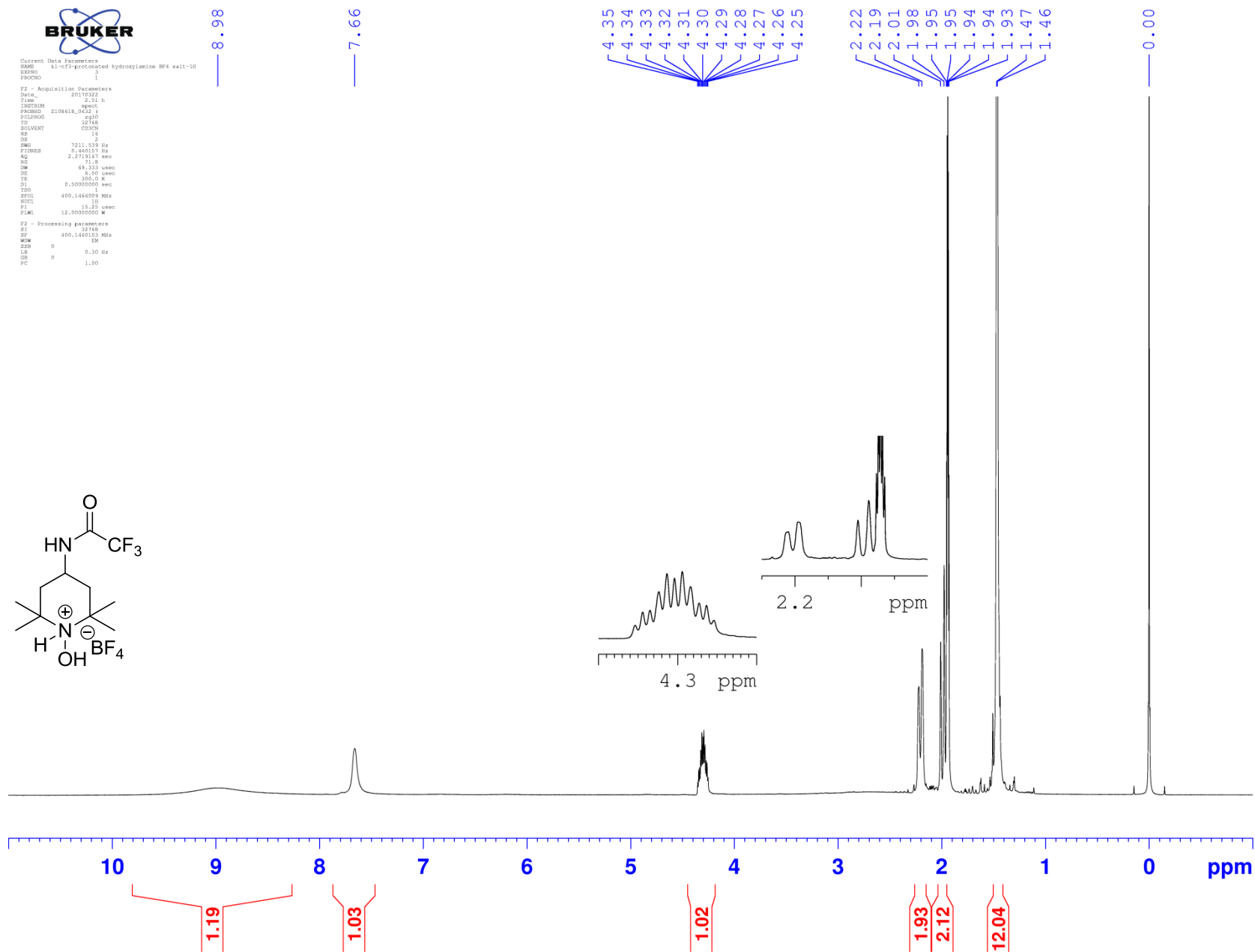
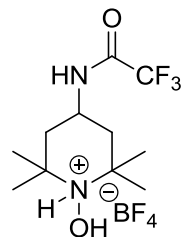
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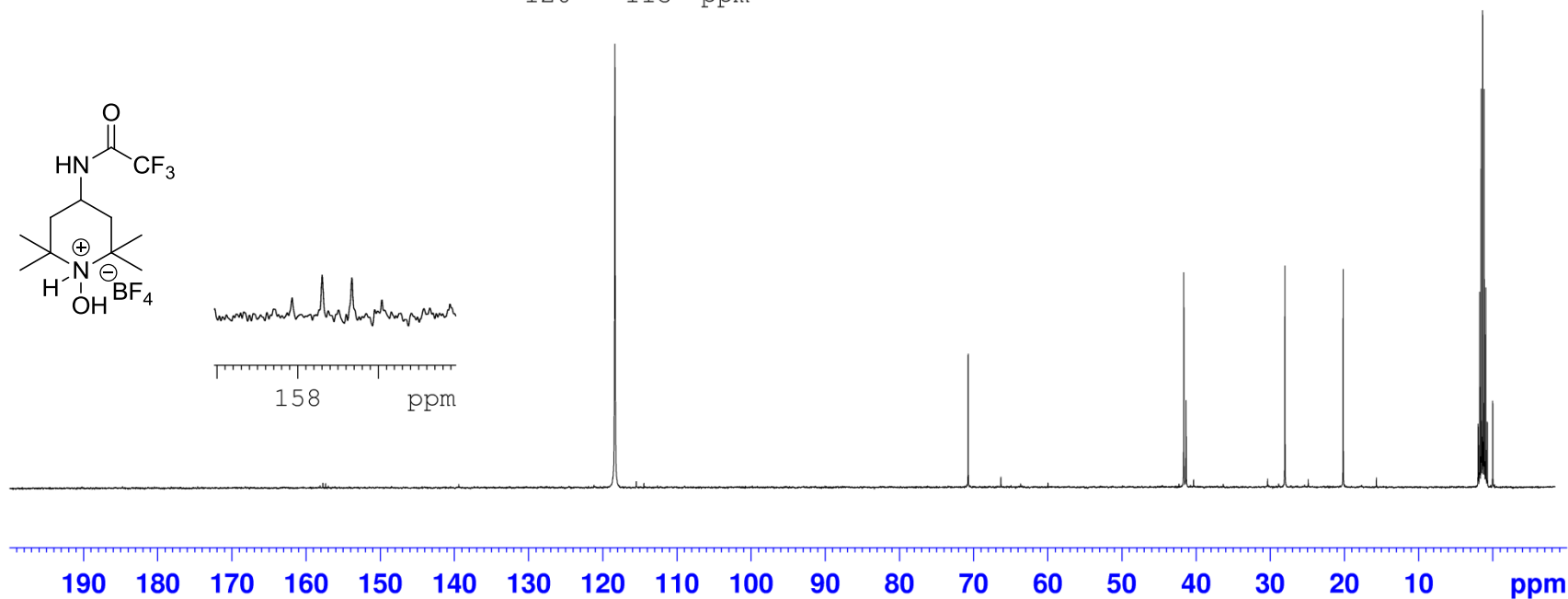
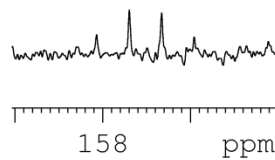
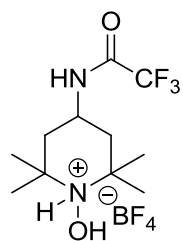
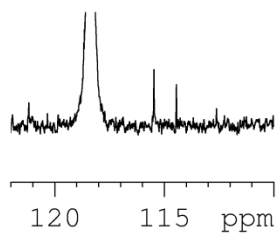
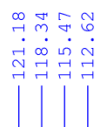
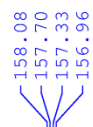
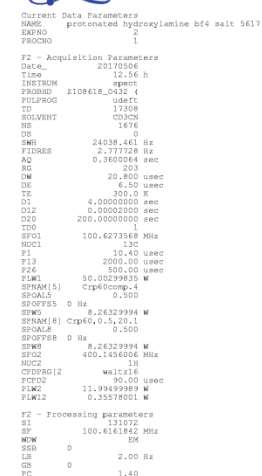
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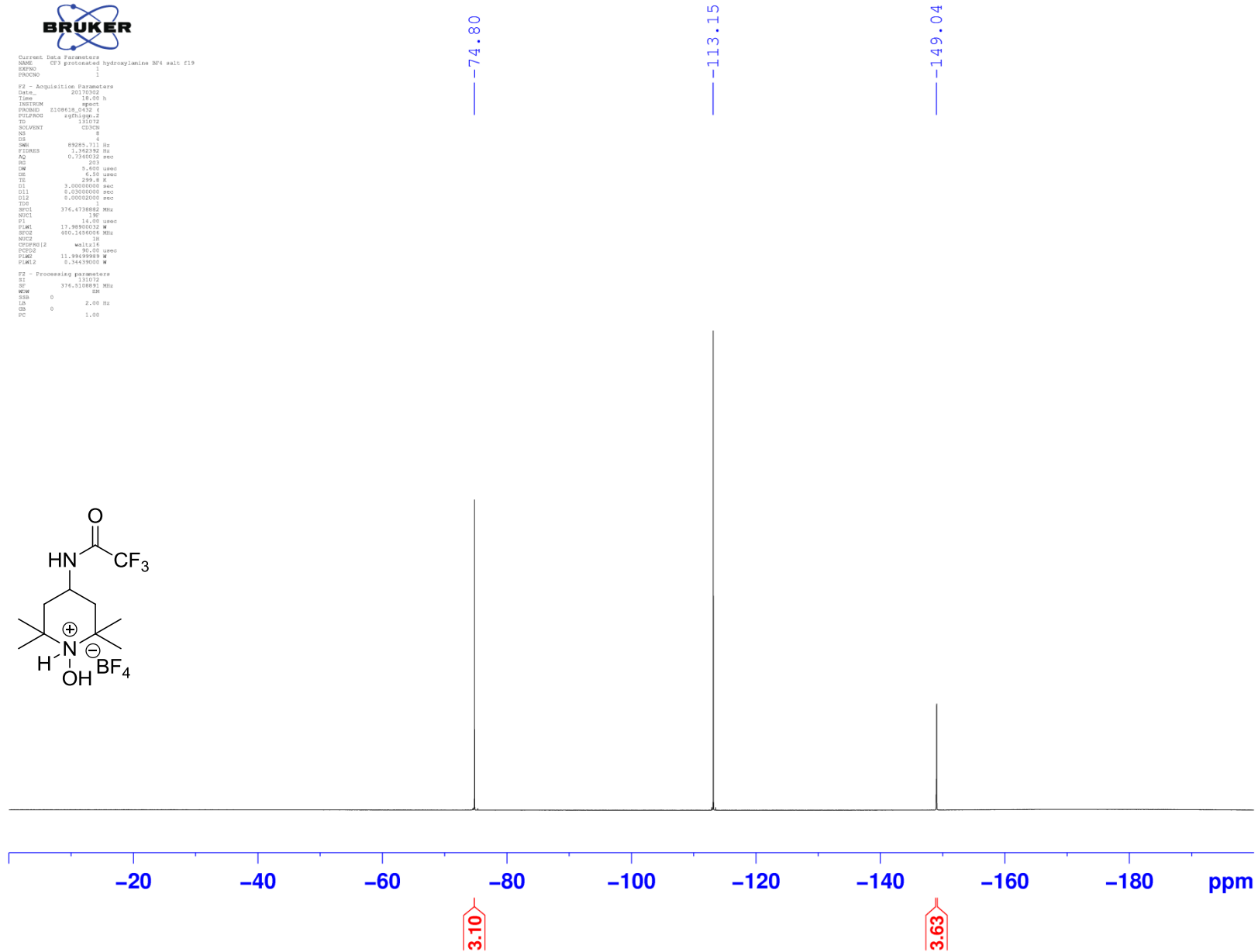
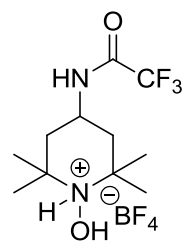
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DE: 16.05 umso
TE: 299.8 K
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D11: 0.03000000 sec
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TD0: 1
T0: 376.478882 MHz
NUC1: 1H
P1: 14.00 umso
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CFOF02: waltz16
NUC3: 19F
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PART II.

CONFORMATIONAL STUDIES OF SATURATED HETEROCYCLES: THE IMPORTANCE OF ELECTROSTATIC INTERACTIONS

CHAPTER I. INSIGHTS INTO CONTRASTING EFFECTS WITHIN SATURATED HETEROCYCLES

1.1 Introduction to Some Historical Aspects of Conformational Analysis in Heterocycles

In 1955, J. T. Edwards reported¹ that an alkoxy group in a pyranose sugar located on C1 preferentially occupies the axial position as opposed to the equatorial position. This is in contrast to typical conformational preferences. (Figure 1-1). Typically, substituents in six-membered ring systems prefer to occupy the equatorial position as it avoids an unfavorable 1,3-diaxial steric interaction between the substituent and the hydrogens across the ring on C3 and C5 (Figure 1-1).

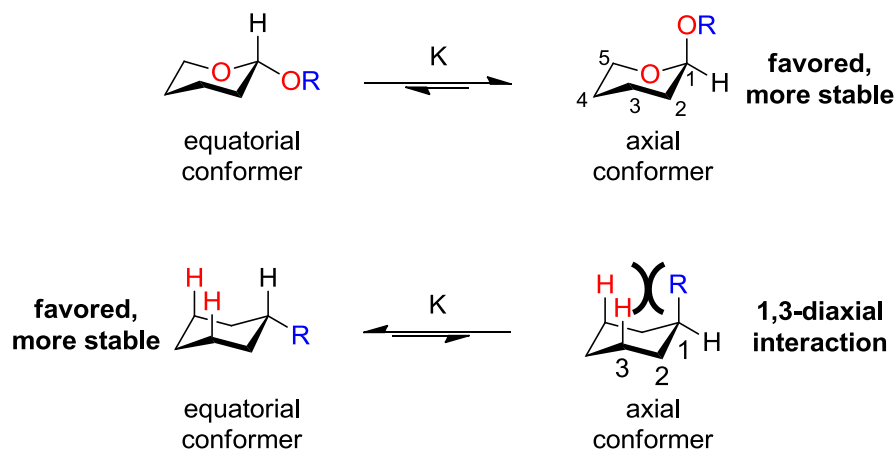


Figure 1-1

Concurrently, N. J. Chü and R. U. Lemieux² were investigating the conformational equilibria of acylated aldohexopyranoses (Figure 1-2). They found that in the acylated derivatives, the acetoxy group on C1 preferentially adopted the axial orientation when the acetoxy groups on C1 and C2 are *cis* ($\Delta G^\circ = -$

0.94 kcal/mol), and even more so when the gauche interactions between the groups on C1 and C2 are removed and the groups are arranged *trans* to one another ($\Delta G^\circ = -1.48$ kcal/mol).

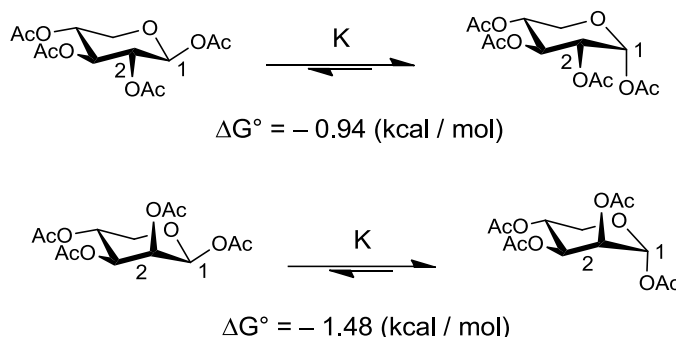


Figure 1-2

A few years later the term “anomeric effect” was coined for this surprising contrasteric phenomenon.³ The effect is not exclusive to carbohydrate chemistry nor heterocycles, thus the “generalized anomeric effect” is stated to be: “The preference for the gauche conformation exhibited by gem-dihetero moieties of type R–X–C–Y (X = more electronegative atom than carbon, O, N, S, etc.; Y = an atom having unshared pairs of electrons).”⁴ The Newman projection down the X–C bond helps to rationalize the “generalized anomeric effect”; the gauche conformer is electronically more stable (Figure 1-3). This is the case since Y, being electronegative and containing lone pairs itself, is oriented furthest away from the lone pairs contained on X, thus reducing electronic repulsion leading to its greater stability. The electrostatic interactions between the lone pairs of electrons on X and the electrons contained on Y is just one of the many arguments as to why the anomeric effect is prevalent in these types of systems.

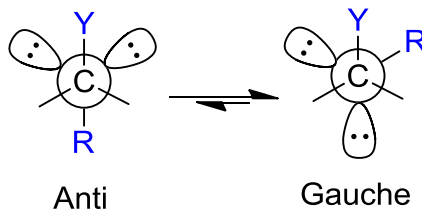


Figure 1-3

A well-known example, in which these electrostatic interactions play a significant role in determining conformational preferences in acyclic systems, is the observation that the methyl groups on

C2 and C3 of butane are arranged anti to one another in the most stable conformation, whereas, in 1,1-dimethoxymethane, the methoxy substituent and the methyl of the other methoxy group are most stable when they are arranged gauche to one another; this phenomenon is commonly referred to as the “gauche effect”^{3J-L} (Figure 1-4).

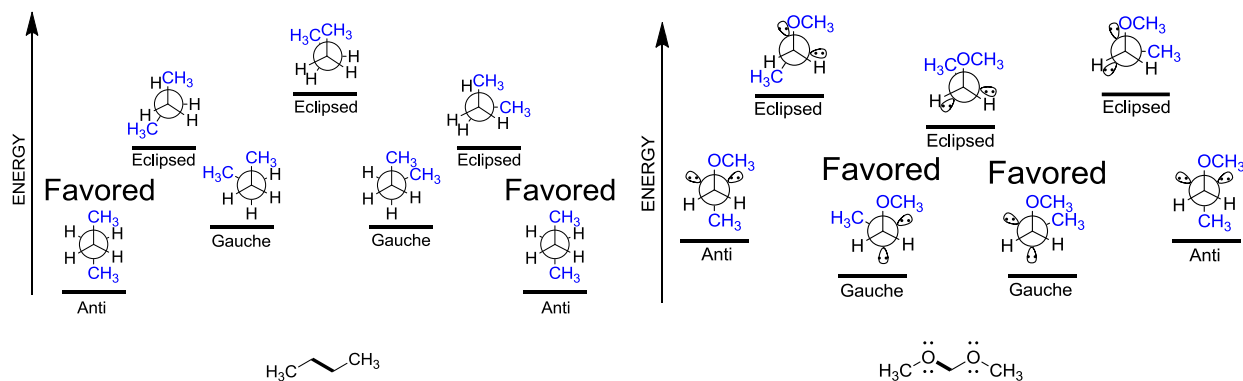


Figure 1-4

The “anomeric effect” and anomeric-like interactions have been investigated in the 1,3-dioxane system. The inclusion of two oxygens within the ring amplifies any anomeric-like contributions. By employing anancomeric systems (Figure 1-5) converts the conformational equilibrium into an equilibrium between diastereomers. Provided that an equilibrium can be established between such diastereomers, the conformational energy difference can be measured quite accurately.

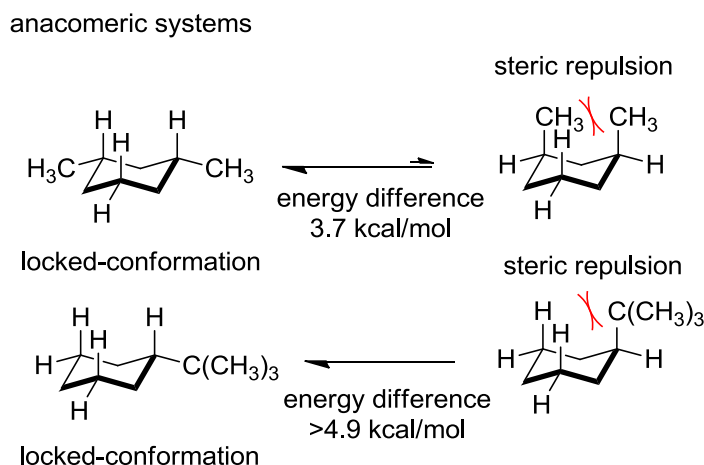


Figure 1-5

In the case of the 1,3-dioxane system, analysis of the acid-catalyzed equilibrium (Figure 1-6) by gas-liquid chromatography allows determination of the equilibrium constant (K), which in turn is related to the free energy difference (ΔG°) by the following equation: $\Delta G^\circ = -RT\ln K$.

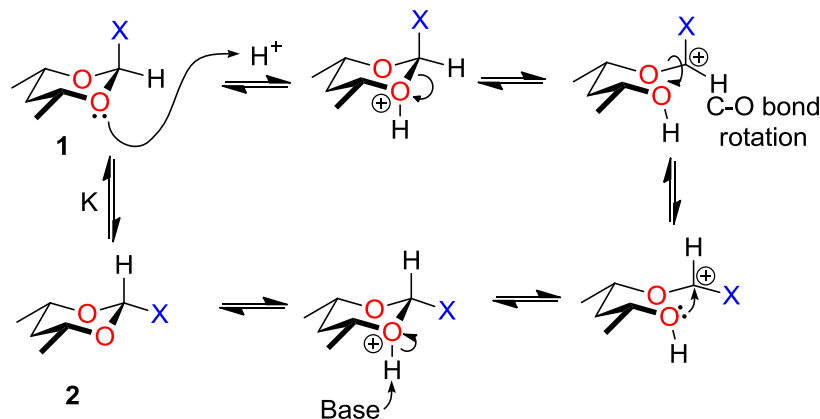
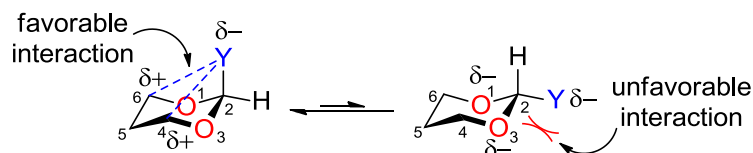


Figure 1-6

Two different explanations have been offered for the origin of the anomeric effect based on electrostatic interactions. In 1,3-dioxane systems the carbons at the 4 and 6 positions of the ring contain an induced positive charge due to the oxygens within the ring (Figure 1-7). The oxygens bear two lone pairs of electrons and obviously contain an induced negative charge. Y being an electronegative atom such as a halogen or an oxygen of an alkoxy group, also contains a slightly negative charge due to the presence of lone pairs of electrons. In a system where the normal anomeric effect is observed, these contributions likely play a role to some extent to help stabilize the axial conformer and destabilize the equatorial conformer (Figure 1-7). There are some systems in which a the “reverse anomeric effect” is observed^{2, 4, 5}; that is, in which the equatorial isomer is favored over the axial isomer. Coxon⁶ invoked the individual partial charges as a way to explain the anomeric effect, which nicely accounts for anomalies such as the reverse anomeric effect. As shown in (Figure 1-7), in systems where the electronegative atom, Y, is positioned one carbon away from the anomeric carbon, a reverse anomeric effect has been postulated to exist.⁴ The induced charges on the carbons at the 4 and 6 position of the ring now interact in a repulsive manner as the carbon containing Y now has an induced positive charge due to the electron-withdrawing effects of Y; this destabilizes the axial conformer, and inspecting the arrangement of the

equatorial conformer suggests a favorable interaction between the slightly positive carbon bearing Y and the negatively charged oxygen within the ring, thus stabilizes the equatorial isomer. The true contribution of electrostatic interactions is hard to quantify, but conveniently offers an explanation for systems that display the “reverse anomeric effect”.⁴

normal anomeric effect:



reverse anomeric effect:

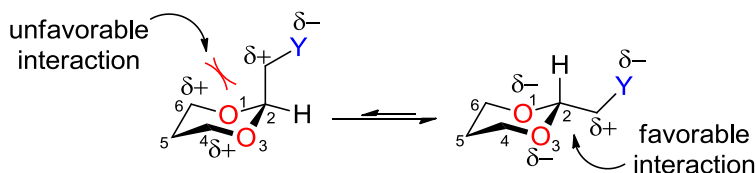


Figure 1-7

As detailed above, minor induced charges affect the stability of specific systems, and the same holds true for the overall dipole of each isomer (axial and equatorial). The equatorial isomer has a larger overall dipole as the individual dipoles induced by the ring heteroatom(s) is additive with the dipole of the equatorial electronegative substituent. Whereas the axial isomer has the lower overall dipole since the individual dipole moments within the molecule are opposing, thus has a lower overall energy and greater stability (Figure 1-8); this is offered as the general explanation of the electrostatic model for the anomeric effect.⁷ It also helps to explain the solvent effects observed for these systems, where polar solvents have been observed to stabilize the molecule with the larger dipole moment. Electrostatic interactions however, are not the only proposed explanation for the cause of the anomeric effect. Controversy surrounds the implication of electrostatic interactions as the sole cause of the anomeric effect, due to the lack of experimental evidence provided to explain the differences in bond lengthening and shortening within anomeric systems.⁸

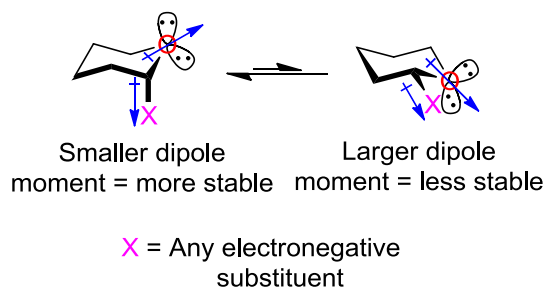


Figure 1-8

The most commonly offered explanation for the anomeric effect is the hyperconjugation model which was suggested by Altona in the late 1950's.^{9,10} It was proposed that the delocalization of the lone pairs on the oxygen within the ring system to the vacant antibonding orbital σ_{CY}^* stabilizes the axial conformer.

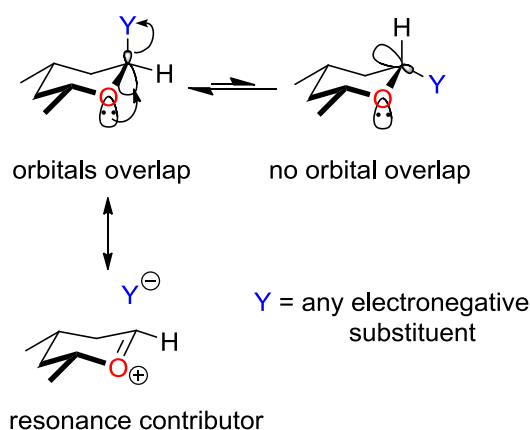


Figure 1-9

As shown previously (Figure 1-3), the gauche conformer allows for this antiperiplanar donation to occur, and the antibonding orbital of Y functions as the acceptor (Figure 1-9). The geometry of the anti conformer does not allow such donation to occur, thus is less stable due to the absence of such hyperconjugative interactions. This donation increases the double bond character of the C(2)–O bond within the ring, but weakens the C(2)–Y bond.¹¹ This is offered as the explanation of why the C(2)–O bond is shortened and the C(2)–Y bond is lengthened in the axial conformer. However, if this were the only contribution to the anomeric effect, it would not provide an explanation of the reverse anomeric

effect.. Additionally, a recent computational study has been conducted that suggests that hyperconjugative interactions are not responsible for the anomeric effect.¹¹

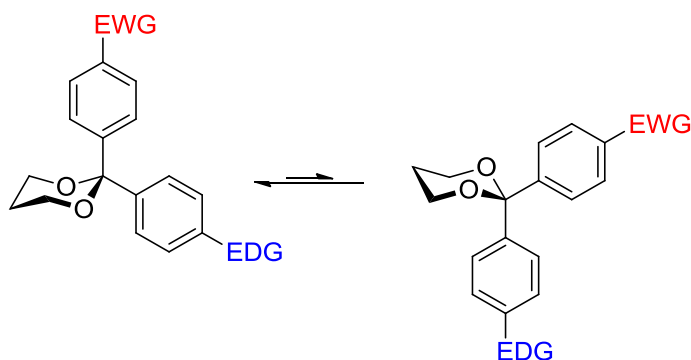
Since the late 1950's there have been various proposals made to help explain the origin of the anomeric effect, but the origin remains obscure. It is unclear as to the exact source of the contrasteric phenomena, and for that matter, as to which model, electrostatic interactions or stereoelectronic effects such as hyperconjugation, best account for its existence. Additional experimental insight into the cause of the anomeric effect would better help predict reactivity and stability of small heterocyclic systems, especially in the fields of carbohydrate and sugar chemistry; this work aims to provide such.

1.2 The Effect of Remote Aryl Substituents on the Conformational Equilibria of 2,2-Diaryl-1,3-dioxanes¹²

Conformational issues lie at the heart of many chemical problems, but it is often difficult to determine the etiology of the conformational preference. This is certainly the case for the anomeric effect, a phenomenon that has been the subject of numerous studies and reviews.³ As described above, one popular explanation for the effect, first suggested by Altona some 60 years ago,⁹ is a hyperconjugative interaction involving electron delocalization of a lone pair into an adjacent C-X σ^* -antibonding orbital. More recently, Mo¹¹ made use of valence bond theory to provide evidence that hyperconjugative interactions are not responsible for the anomeric effect and concluded that it is better interpreted as involving electrostatic interactions. In this connection, it is of some historical interest to note that electrostatic interactions were invoked by Lemieux and Chu, who coined the term “anomeric effect” in 1958, to account for the preference of axial over equatorial C(1) alkoxy groups in pyranose sugars.²

As a result of our interest in conformational preferences in substituted 1,3-dioxanes,^{4, 13} we made note of a 1999 report by Sato and coworkers dealing with the conformations of *para*-substituted 2,2-diphenyl-1,3-dioxanes.¹⁴ These authors made the prescient suggestion that the geminal aryl rings have the same steric bulk and, consequently, the conformations preferentially adopted by such molecules, depicted below in scheme 1-1, should reflect the effect of the remote *para*-substituents on the conformational

equilibria. Their NMR studies and X-ray crystallographic analyses of conformationally unbiased substrates led to the conclusion that the aryl group bearing the more electron-withdrawing *p*-substituent (EWG) preferentially occupies the axial position and that the axial C(2)-aryl bond is significantly lengthened; they attributed this result to the operation of an anomeric effect involving a hyperconjugative interaction. This preference was in contrast to experimental observations that in hexane solvent, 2-*p*-(trifluoromethyl)phenyl-1,3-dioxane ($\Delta G^\circ = -3.08 \pm 0.02$ kcal/mol) prefers the equatorial position by 0.22 kcal/mol over 2-phenyl-1,3-dioxane ($\Delta G^\circ = -2.86 \pm 0.02$ kcal/mol); although at the time of dissemination of this work, the free energy difference was not fully addressed.⁴



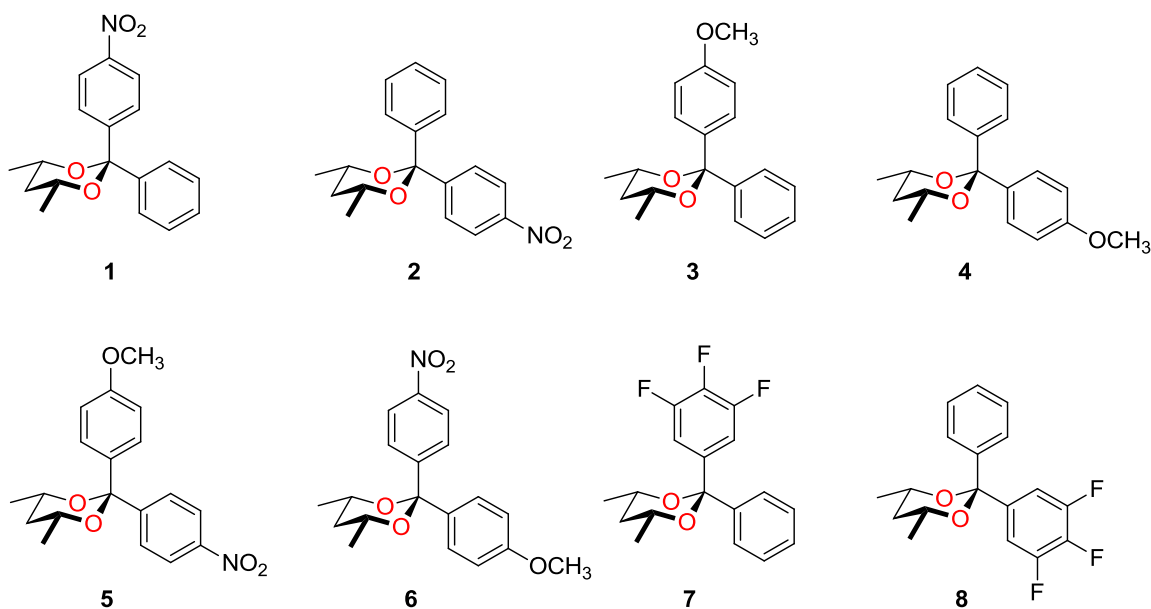
Scheme 1-1

There was one disquieting observation in the account by Sato and coworkers¹⁴: they reported PM3 calculations that adequately reproduced the observed geometries but which indicated the opposite conformational preference for the *p*-substituted 2,2-diphenyl-1,3-dioxanes than that indicated by the crystallographic analyses; that is, the PM3 calculations suggested that the more electron-rich aryl group (EDG) should preferentially adopt the axial position.

The conclusions of Sato and coworkers, which were drawn from analysis of conformationally unbiased substrates whose crystal structures did not reflect the predominant conformation in solution, were incorrect. Remote substituents on the aryl rings do indeed have a considerable effect on conformational equilibria of 2,2-diphenyl-1,3-dioxanes. However, a hyperconjugative anomeric effect is likely not the correct explanation for the conformational behavior in these systems. As detailed below, analysis of the acid-catalyzed equilibria between configurationally isomeric 2,2-diphenyl-*cis*-4,6-

dimethyl-1,3-dioxanes bearing remote aryl substituents has established that electrostatic interactions are most likely responsible for the observed energy differences between isomers.

Chart 1-1



Seminal work by Eliel and coworkers has demonstrated that conformational equilibria of the sort depicted above are investigated most conveniently by acid-catalyzed equilibration of configurationally isomeric models for the conformational isomers and a *cis*-4,6-dimethyl-1,3-dioxane is a good surrogate for the unbiased system.¹⁵ To this end, a representative series of anancomeric 2,2-diaryl-*cis*-4,6-dimethyl-1,3-dioxanes (**1** – **8**), depicted in Chart 1-1, were prepared by condensation of the appropriate benzophenone with *meso*-2,4-pentanediol. Fortunately, as suggested by the report by Nichols and coworkers,¹⁶ it was not necessary to separate the *meso* diol from its racemic isomer: the ketone reacts preferentially with the *meso* diol to afford the desired *cis*-4,6-disubstituted dioxane rather than with the racemic diol to give the much less stable isomer bearing an axial methyl group. Thus, condensation of 2,4-pentanediol, consisting of ~60% *meso* and ~40% *dl* isomers,¹⁷ with enough ketone to react with slightly less than the amount of *meso* diol present, provided as the major products the pairs of epimeric 1,3-dioxanes illustrated in Chart 1-1 along with a small quantity of the unwanted *trans*-4,6-dimethyl

isomer. With some considerable effort, the 2,2-diaryl-*cis*-4,6-dimethyl-1,3-dioxanes epimers were separated chromatographically and recrystallized to give analytically pure solids.

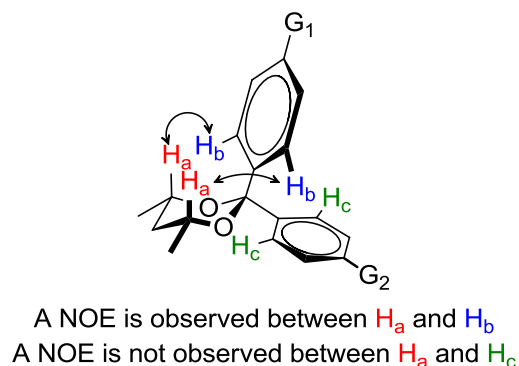


Figure 1-10

The configuration of the individual 2,2-diaryl-*cis*-4,6-dimethyl-1,3-dioxanes were assigned by ^1H NOESY analysis of the interaction between the *ortho* protons of the axial aryl ring and the *syn*-axial protons at C(4,6) of the dioxane as illustrated in Figure 1-10 and detailed in the Experimental Section. Additionally, the structures of compounds **1**, **2**, **3**, and **4** were secured by X-ray crystallographic analysis; the structures, which are fully in accord with those assigned by NOESY analyses, are portrayed in Figure 1-11.

Each of the 2,2-diaryl-*cis*-4,6-dimethyl-1,3-dioxane epimers were equilibrated at room temperature, as illustrated in Table 1-1 in sealed vials or ampoules as solutions in cyclohexane, diethyl ether, and acetonitrile over Amberlyst-15 resin. Equilibrium was approached independently from pure samples of each isomer and, after neutralizing the solutions by shaking with anhydrous K_2CO_3 , the area ratio of the isomers was determined by GC analysis that provided baseline separation. When the same area ratios were obtained from initially pure samples of each epimer, it was deemed that equilibrium had been attained. Area ratios for each equilibrium were taken as the average of 8 – 22 determinations from each side and the free energy difference was calculated from this equilibrium constant as $\Delta G^\circ = -RT \ln K$. The results of these studies are summarized in Table 1-1.

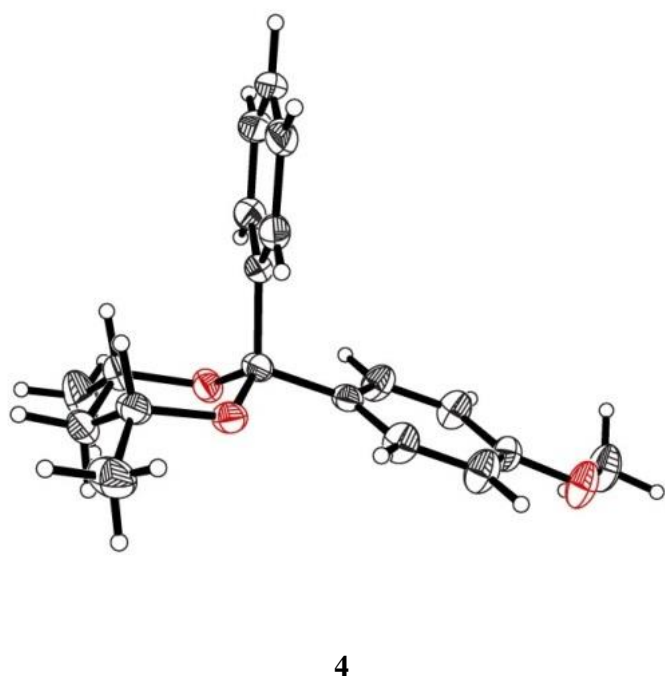
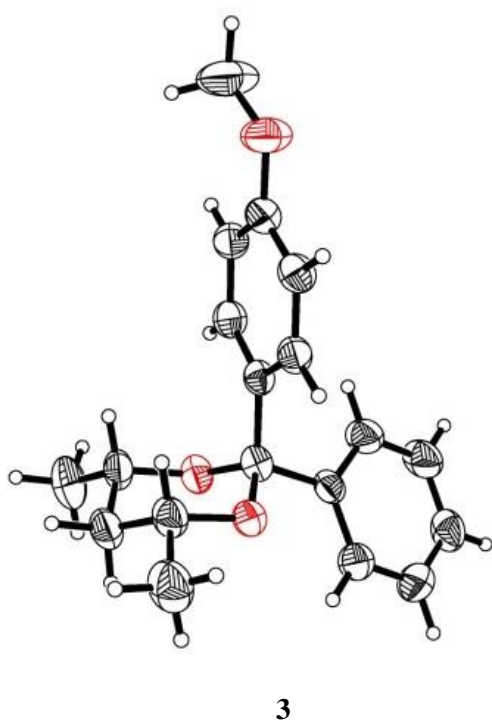
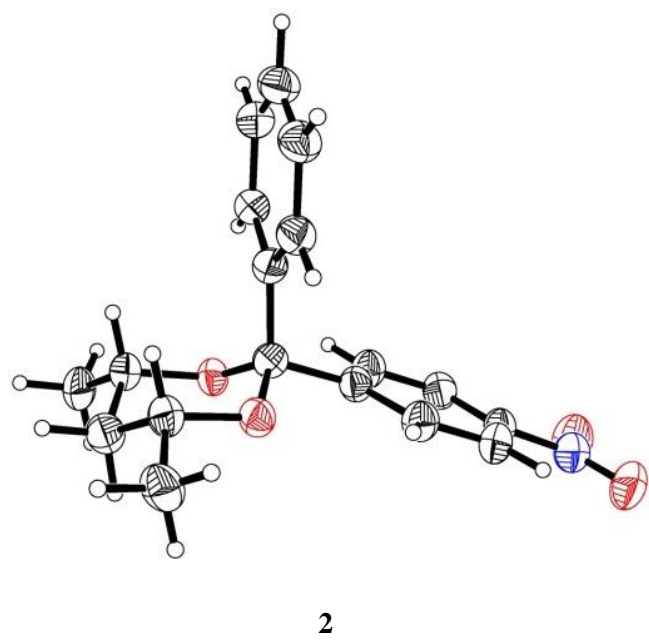
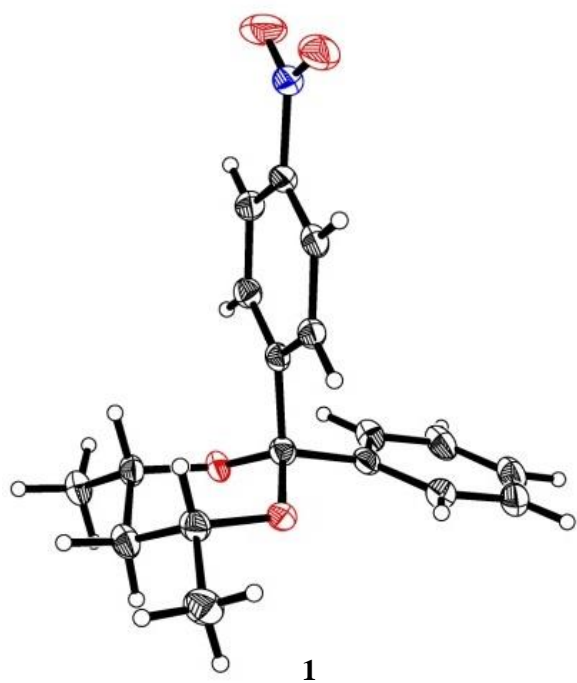


Figure 1-11¹⁸

Table 1-1

entry	epimers	solvent	ΔG° , ^a kcal/mol
1	 <div style="display: flex; justify-content: space-around;"> 1 2 </div>	<i>c</i> -C ₆ H ₁₂	not determined ^b
2		Et ₂ O	-1.31 ± 0.03
3		CH ₃ CN	-0.424 ± 0.001
4	 <div style="display: flex; justify-content: space-around;"> 3 4 </div>	<i>c</i> -C ₆ H ₁₂	0.080 ± 0.003
5		Et ₂ O	0.038 ± 0.002
6		CH ₃ CN	-0.023 ± 0.002
7	 <div style="display: flex; justify-content: space-around;"> 5 6 </div>	<i>c</i> -C ₆ H ₁₂	not determined ^c
8		Et ₂ O	0.78 ± 0.01
9		CH ₃ CN	0.199 ± 0.003
10	 <div style="display: flex; justify-content: space-around;"> 7 8 </div>	<i>c</i> -C ₆ H ₁₂	-0.64 ± 0.01
11		Et ₂ O	-0.43 ± 0.01
12		CH ₃ CN	-0.101 ± 0.004

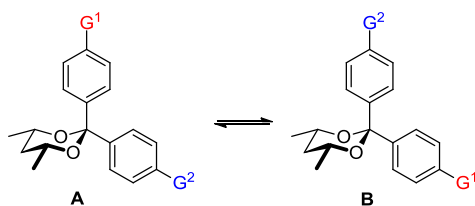
^aDetermined at 23 °C; errors are propagated standard deviations. ^bEquilibrium was not attained over the course of months. ^cDifferences in the solubilities of **5** and **6** in cyclohexane precluded equilibration; **5** is quite soluble in cyclohexane but **6** (the less stable isomer) precipitates from the equilibration solution.

Cursory inspection of the data presented in Table 1-1 demonstrates that the phenyl ring bearing the more electron-withdrawing substituent prefers to adopt the equatorial position at C(2) in 1,3-dioxane. These results are clearly contrary to the experimental observations reported by Sato and coworkers, but they are in accord with their semi-empirical MO calculations.¹⁴ It would appear that recrystallization of the conformationally mobile *p*-substituted 2,2-diphenyl-1,3-dioxanes used in the previous study led to the isolation of the less stable isomers. Before further discussion of the experimental results, it is instructive to consider the results of DFT calculations of the geometry and energetics of 2,2-diphenyl-*cis*-4,6-dimethyl-1,3-dioxanes bearing remote aryl substituents.

In an effort to gain some insight into the factors responsible for the experimental results presented in Table 1-1, the 2,2-diaryl-*cis*-4,6-dimethyl-1,3-dioxanes were computationally explored at the B3LYP/6-311+G* level¹⁹ using tight convergence criteria (opt = verytight, int = ultrafine)²⁰ for both the optimizations and for calculation of the thermal corrections; all of the following data are for 298 K. The calculated enthalpies (ΔH°) and free energies (ΔG°) for the 1,3-dioxanes that were examined are summarized in Table 1-2. Using the tight optimization limits, the values of ΔH° and ΔG° are close to each other as might be expected for such similar compounds (e.g., $\Delta S^\circ \sim 0$). With compounds such as these, having many low frequencies, the correction from 0 K, as in the DFT calculations, to 298 K is more reliable for ΔH° than for ΔG° and the former will be used in the following discussion when there is a significant difference between the values.

It might be noted that the computed geometries are in excellent agreement with the structures determined by X-ray crystallography. This aspect was investigated, as detailed in the Experimental Section, by mapping the crystallographic coordinates for compounds **1** and **2** onto the coordinates produced by computational optimization. The root mean square deviations (RMSDs) between atomic coordinates of all the non-hydrogen atoms of compounds **1** and **2** and the corresponding calculated atom positions had an average RMSD of 0.0852 Å for **1** and 0.0913 Å for **2**. Overall, the crystallographic and computational structures are remarkably similar.

Table 1-2



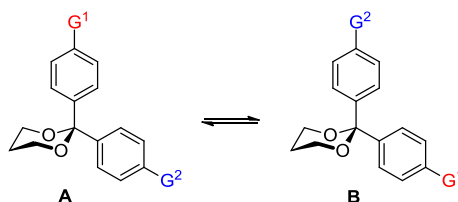
entry	G^1	G^2	A, $\mu(D)^a$	B, $\mu(D)^a$	$\Delta H^\circ, ^b \text{ A} \rightarrow \text{B}$	$\Delta G^\circ, ^b \text{ A} \rightarrow \text{B}$
1	NH ₂	H	2.701	1.036	0.22	0.21
2	OCH ₃	H	2.867	2.037	0.07	0.05
3	F	H	2.287	4.151	-0.26	-0.24
4	Cl	H	2.364	4.387	-0.24	-0.24
5	CF ₃	H	3.334	5.949	-0.39	-0.43
6	CN	H	4.939	7.702	-0.55	-0.53
7	NO ₂	H	5.255	8.037	-0.65	-0.65
8	NO ₂	OCH ₃	6.371	8.457	-1.07	-0.92
9	3,4,5-trifluoro	H	3.633	6.151	-0.54	-0.55

^a Dipole moment. ^b Kcal/mol; values are corrected for both differences in ZPE and the change in enthalpy on going from 0 K (corresponding to the calculations) to 298 K.

The analogous conformationally mobile 2,2-diaryl-1,3-dioxanes lacking methyl groups were also examined at the same level of theory (Table 1-3) and gave essentially the same results as those given in Table 1-2. Thus, as one might reasonably expect, the *cis*-4,6-dimethyl groups have a negligible effect on the conformational preference of the substituted phenyl rings. It can be seen from the computational results presented in Table 1-2 that, in all cases, the isomer having the higher dipole moment, and having the electron-withdrawing group in the equatorial phenyl ring and / or the electron-donating group in the axial ring, is predicted to have the lower energy. That the higher dipole moment isomer is predicted to be more stable than its lower dipole moment epimer may seem surprising,¹ but this conclusion is fully consistent with the equilibration studies (Table 1-1). Indeed, the calculated ΔH° values in Table 1-2, which refer to the gas phase, are remarkably similar to the experimentally determined ΔG° values in

cyclohexane (Table 1-1, entries 4 and 10), the least polar solvent used in the equilibration studies. The experimental free energy difference between **3** and **4** ($\Delta G^\circ = 0.08$ kcal/mol) as well as the value for **7** and **8** ($\Delta G^\circ = 0.64$ kcal/mol) match well with the computed ΔH° values of 0.07 and 0.54 kcal/mole, respectively, for these epimeric pairs (Table 1-2, entries 2 and 9). Unfortunately, as noted in Table 1-1, it was not possible to establish equilibrium in cyclohexane solution between the 1,3-dioxanes bearing NO₂-substituted phenyl rings as the epimeric pairs had not reached equilibrium even after 18 months.

Table 1-3



entry	G ¹	G ²	A, $\mu(\text{D})^a$	B, $\mu(\text{D})^a$	$\Delta H^\circ, ^b \text{ A} \rightarrow \text{B}$	$\Delta G^\circ, ^b \text{ A} \rightarrow \text{B}$
1	NH ₂	H	2.750	0.983	0.30	0.37
2	OCH ₃	H	2.887	2.031	0.07	0.06
3	F	H	2.189	4.118	-0.25	-0.17
4	Cl	H	2.248	4.436	-0.28	-0.20
5	CF ₃	H	3.190	5.895	-0.43	-0.51
6	CN	H	4.773	7.633	-0.52	-0.42
7	NO ₂	H	5.073	7.960	-0.67	-0.64
8	NO ₂	NH ₂	6.324	8.014	-1.01	-1.00
9	NO ₂	OCH ₃	5.333	8.408	-0.78	-0.74
10	2,5-difluoro	H	2.882	1.067	1.29	1.41
11	pentafluoro	H	2.568	4.865	0.85	0.89
12	3,4,5-trifluoro	H	3.478	6.089	-0.52	-0.45

^a Dipole moment. ^b Kcal/mol; values are corrected for both differences in ZPE and the change in enthalpy on going from 0 K (corresponding to the calculations) to 298 K.

The equilibration results demonstrate that the energy difference between each pair of epimeric *p*-substituted 2,2-diaryl-*cis*-4,6-dimethyl-1,3-dioxanes decrease as the polarity of the solvent increases. In the case of the *p*-methoxy pair (**3** and **4**), the preference for the isomer having the axial anisyl group, seen in cyclohexane and Et₂O solution, is reversed in CH₃CN. Given that the substituted 1,3-dioxanes are highly polar, one would expect that the difference in energy between epimeric pairs would vary in a polar medium where the electrostatic energies become small. However, it may seem surprising that the lower dipole moment isomer is apparently stabilized vis-à-vis the epimer of higher dipole moment as the solvent polarity is increased. However, in most cases, the dipole is associated with a small group of atoms within a molecule; this is not true in the present case. The dipole moment of 1,3-dioxane is 2.23 D. Thus, the difference in dipole moments between epimers is largely due to an equatorial *p*-substituted aryl ring, having the substituent dipole oriented to enhance the ketal dipole, whereas it has less of an effect on the overall dipole moment when it is in the axial position.

In addition to the substituents listed in Table 1-2, the pentafluorophenyl epimers were examined. As illustrated in Scheme 1-2, the isomer having an axial pentafluorophenyl is computed to be more stable ($\Delta G^\circ = 1.22$ kcal/mol) than its equatorial epimer. This axial preference, which contrasts to that of a *p*-fluorophenyl ($\Delta G^\circ = -0.24$ kcal/mol) or a 3,4,5-trifluorophenyl ring ($\Delta G^\circ = -0.55$ kcal/mol), is almost certainly related to a steric / electrostatic interaction involving the *ortho*-fluorine atoms and the oxygens of the 1,3-dioxane ring. Indeed, the 2,6-difluorophenyl group, lacking the more remote fluorines, prefers to adopt the axial orientation to an even greater extent ($\Delta G^\circ = 1.29$ kcal/mol) than its pentafluoro analog.

The observed substituent effects are remarkably well reproduced by the calculations. In large measure this is likely due to the structural similarity between a given pair of epimers. The *p*-substituents are relatively far removed from the ketal center and one would expect a large degree of cancellation of corresponding local atomic energies with the substituent providing only a small perturbation. The agreement between experimental and computed energy differences suggests that an analysis of the calculated results might lead to an explanation of the substituent effects.

The application of linear free energy relationships to probe substituent effects has a long history beginning with Hammett.²¹ We have applied his use of σ_p constants²² in the form of a plot giving the results shown in Figure 1-12. There is a very good linear correlation ($r = 0.98$), giving a slope (ρ) of -0.6 , using either the calculated ΔH° or ΔG° values (Table 1-2). The sign of the slope (ρ -value) suggests that the charge at the *ipso*-carbon of the phenyl ring attached to the C(2) ketal center becomes more positive as the substituent becomes more electron-withdrawing.

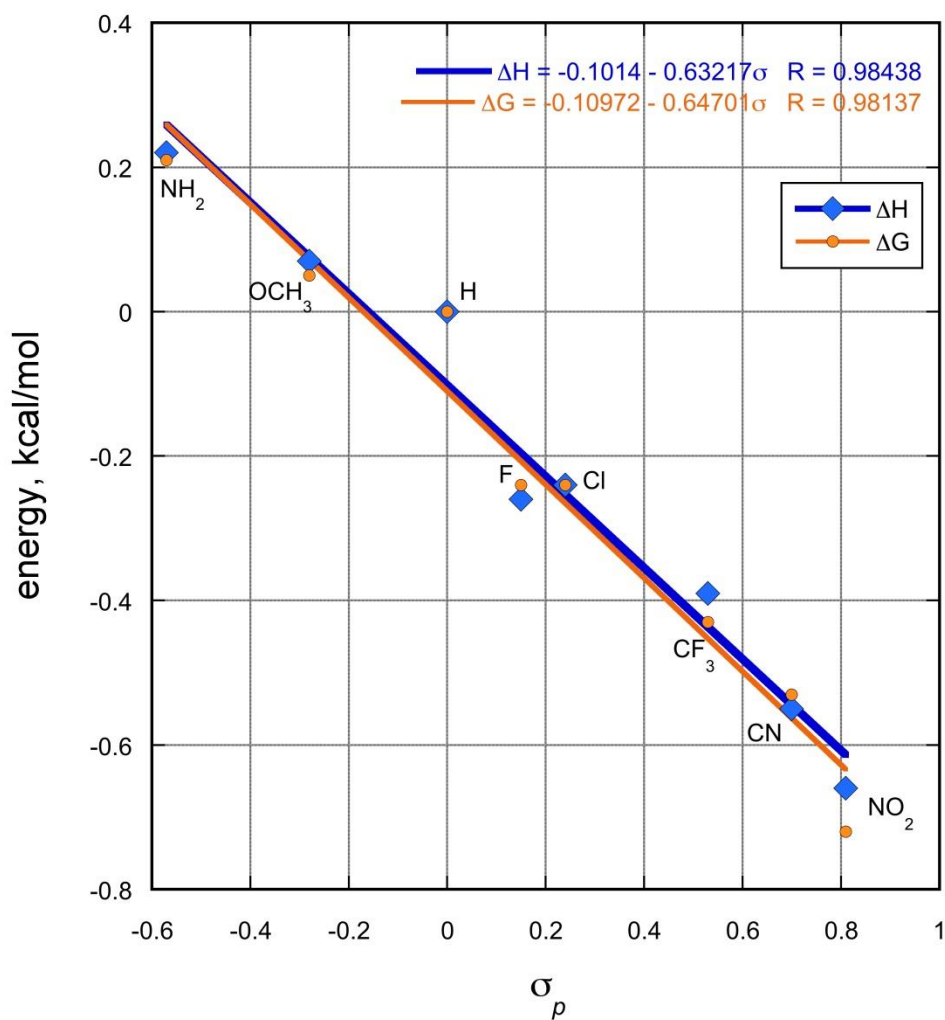


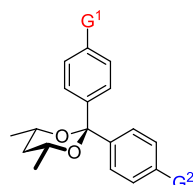
Figure 1-12

This conclusion is further reinforced by noting the effect of substituents on the bond length between the aryl rings and the C(2) ketal center; they are given in Table 1-4. In all cases, as would be expected on the basis of steric interactions,²³ the bond between C(2) and an axial phenyl ring is longer

than the corresponding bond to an equatorial phenyl in both the parent molecule (Table 3, entry 5) and the *p*-substituted molecules. With the axial substituents, the C(2) to axial ring distances, by and large, increase as the *para*-substituent is varied from those that are electron-donating to those that are electron-withdrawing. As noted above, the *ipso*-carbon of the aryl ring becomes more positive as the aryl substituent becomes more electron-withdrawing. Given that the C(2) carbon is quite positive, this factor accounts for the increase in bond length.

It is possible to make the relationship between the atomic charges and the bond lengths more quantitative. This requires a calculation of the atomic charges from the wave function and this can be done using the method developed by Hirshfeld²⁴ or the modification of this method that has been proposed more recently by Truhlar and coworkers.²⁵ We have calculated both of these charges and found them to be linearly related; the Hirshfeld charges are used in the following discussion.

Table 1-4

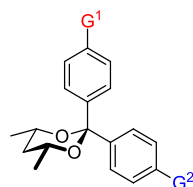


group	substituted ring in axial position (G^1)		substituted ring in equatorial position (G^2)	
	C(2)-axial length	C(2)-equatorial length	C(2)-axial length	C(2)-equatorial length
NH ₂	1.5405	1.5302	1.5444	1.5248
OMe	1.5418	1.5302	1.5450	1.5272
H	1.5445	1.5305	1.5445	1.5305
F	1.5445	1.5303	1.5450	1.5292
Cl	1.5406	1.5302	1.5447	1.5294
CF ₃	1.5460	1.5300	1.5445	1.5305
CN	1.5462	1.5302	1.5445	1.5305
NO ₂	1.5460	1.5303	1.5446	1.5304

The Hirshfeld charges at C(2) and at the *ipso*-position of the substituted aryl rings are listed in Table 1-5. The C(2) charge is largely unaffected by the *p*-substituents whereas the charge at the *ipso*-carbon varies from negative, for a ring bearing a *p*-NH₂, to a small positive value for a *p*-NO₂ group. The relationship between these charges (Table 1-5) and the C(2) to *ipso*-bond lengths of the axial phenyl rings bearing the substituent (Table 1-4) is shown in Figure 1-13. A similar trend is found for the epimers having the substituted ring in the equatorial position.

Could the difference in charges also be the origin of the substituent effects on the axial - equatorial energy differences? It would be tempting to sum all of the Coulombic energies between non-bonded atoms, but it is unlikely that this would be satisfactory. In the first place, the observed effects are quite small for these large molecules and, perhaps more importantly, there is no obvious way in which to implement this seemingly straightforward scheme. It was noted some time ago by Kirkwood and Westheimer that simple two-center calculated Coulombic energies in molecules are moderated by the electric fields associated with the bonds in a molecule.²⁶

Table 1-5



substituent	$G^1 = \text{substituent}$ $G^2 = \text{H}$		$G^1 = \text{H}$ $G^2 = \text{substituent}$	
	C(2)	<i>ipso</i> -carbon	C(2)	<i>ipso</i> -carbon
NH ₂	0.1581	-0.0347	0.1579	-0.0161
OMe	0.1584	-0.0300	0.1583	-0.0164
H	0.1581	-0.0165	0.1581	-0.0165
F	0.1591	-0.0215	0.1586	-0.0127
Cl	0.1594	-0.0175	0.1583	-0.0164
CF ₃	0.1596	-0.0067	0.1595	0.0033
CN	0.1594	-0.0029	0.1590	0.0067
NO ₂	0.1596	0.0007	0.1591	0.0105

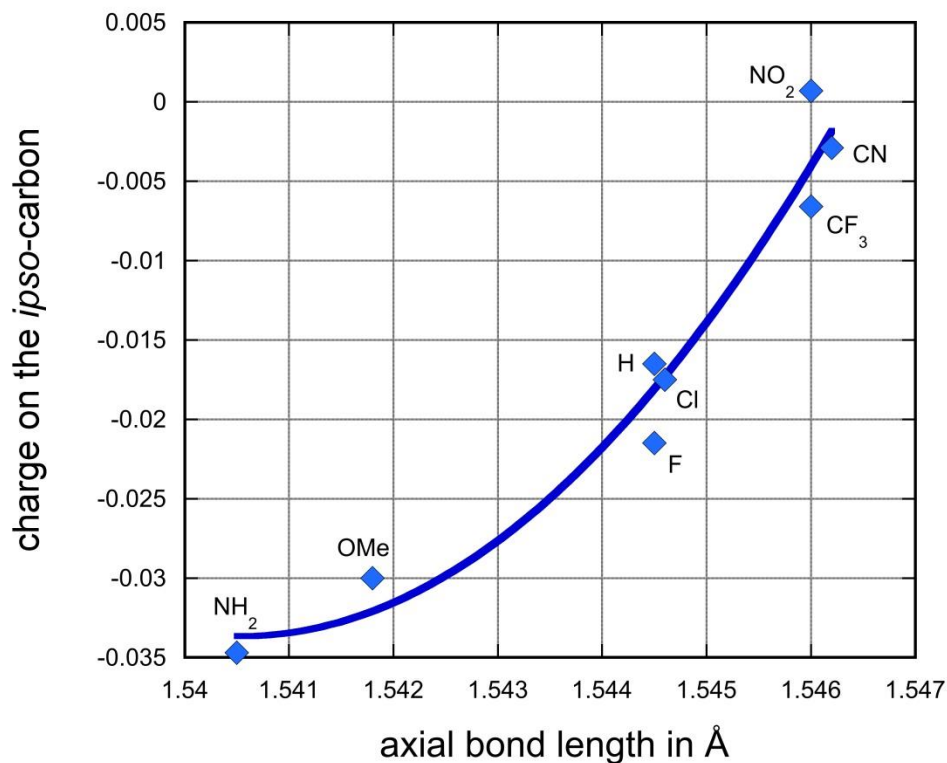


Figure 1-13

Thus, although the observed effects of remote aryl substituents on the conformational behavior of 2,2-diaryl-1,3-dioxanes are well reproduced by DFT calculations, the precise cause (or causes) of the observed effects remain somewhat obscure. It is clear, however, that electrostatic interactions, rather than a hyperconjugative anomeric effect, are responsible for the fascinating conformational behavior of such molecules.

Remote substituents on the aryl rings of 2,2-diphenyl-1,3-dioxanes have a significant effect on the conformational equilibria of such molecules. Both the results of direct equilibration of configurationally isomeric 2,2-diphenyl-*cis*-4,6-dimethyl-1,3-dioxanes bearing remote aryl substituents (Table 1-1) and calculations at the B3LYP/6-311+G* level (Table 1-2) agree that, in all cases, the isomer having the higher dipole moment, and bearing an electron-withdrawing group in the equatorial phenyl ring and / or an electron-donating group in the axial ring, has the lower energy. These results are precisely the opposite of the conclusions reported by Sato and coworkers from their experimental observations drawn from a study of conformationally mobile 2,2-diaryl-1,3-dioxanes.¹⁴

The equilibration results indicate that the energy difference between each pair of epimeric *p*-substituted 2,2-diaryl-*cis*-4,6-dimethyl-1,3-dioxanes decrease as the polarity of the solvent increases. The origin of the energy differences between epimeric pairs of 2,2-diphenyl -1,3-dioxanes bearing remote aryl substituents is likely electrostatic in nature. A Hammett plot, using either the calculated ΔH° or ΔG° values (Table 1-2) versus σ_p constants (Figure 1-12), is linear ($r = 0.98$) with a slope of -0.6 . An analysis of computed atomic charges and bond length changes as the aryl substituents are varied is in accord with an explanation for the experimental results that invokes intramolecular electrostatic interactions as the dominant phenomenon. Unfortunately, as noted above, the specific etiology of the observed effects remains unclear.

1.3 Rotamers of Phenyl Substituted 1,3-Dioxanes and Tetrahydropyrans: Importance of CH \cdots O Coulombic Interactions²⁷

To develop a further understanding of the results presented above¹², 2,2-diphenyl-1,3-dioxane (**1**) was further examined computationally and compared to the corresponding compound (**2**) containing the phenyl ring in the 5-position. These studies indicated large differences in the orientation of the phenyl rings. In **1**, the two rings have a "perpendicular" orientation (i.e., the two rings are perpendicular to the mirror plane of the dioxane ring) whereas in **2** the two rings adopt a strongly twisted perpendicular-like arrangement (Figure 1-14). 1,1-Diphenylcyclohexane (**3**) is similar to **2**, but with the aryl rings somewhat less twisted.

The difference in the rotameric arrangement of the phenyl rings in **1** and **2** must be due to the oxygens, and in order to clarify their effect, we have examined phenyl-substituted 1,3-dioxanes and tetrahydropyrans and compared them with the corresponding phenylcyclohexanes. We have reported a computational study of the latter that found MP2 to be more satisfactory than DFT.^{13c} Therefore, all of these compounds were studied at the MP2/6-311+G* level for the geometry optimizations, the vibrational frequencies and the rotational barrier scans. The results are shown in Table 1-6 and the compounds are shown in Figure 1-14.

Table 1-6

compound	τ (a)	μ (D)	$\Delta H(298)$	$\Delta G(298)$	ΔE^\ddagger (b)
ax-phenylcyclohexane (4)	66.24	0.451	3.24	3.74	1.29
eq-phenylcyclohexane (5)	0.00	0.530	0.00	0.00	3.56
ax-5-phenyldioxane (6)	0.00	2.303	0.83	0.58	3.75
eq-5-phenyldioxane (7)	0.00	2.512	0.00	0.00	3.09
ax-2-phenyldioxane (8)	87.50	2.460	1.13	2.26	7.3
eq-2-phenyldioxane (9)	0.00	2.512	0.00	0.00	0.32 (c)
ax-3-phenylTHP (10)	38.96	1.774	0.72	0.96	3.58
eq-3-phenylTHP (11)	3.73	1.667	0.00	0.00	3.38
ax-4-phenylTHP (12)	60.67	2.303	3.53	4.07	1.38 (d)
eq-4-phenylTHP (13)	0.00	2.512	0.00	0.00	2.86

In all cases, as expected, the compounds with an equatorial phenyl have a lower energy than the corresponding axial substituted isomers. Most of the equatorially substituted compounds (**5**, **7**, **11** and **13**) display a similar preferred rotameric arrangement of the phenyl group, adopting a ‘parallel’ conformation, and all have a rotational barrier of about 3 kcal/mol. The barriers to phenyl rotation in **5**, **7**, **11**, and **13** are largely the result of steric interactions between the *ortho*-hydrogens of the phenyl group and the equatorial H’s of the ring to which it is attached.²⁸ However, equatorial 2-phenyldioxane (**9**) is strikingly different than the other equatorial substituted compounds. The phenyl–C(2) rotational barrier in **9** is only 0.3 kcal/mol with equal energetic minima at $\tau = 0$ and 90° (Figure 1-15). An experimental study found this compound to have a very small barrier.^{13a,29} This low barrier must be related to the dioxane oxygens since this is the only source of a difference with respect to the other compounds. In **9** the destabilizing *ortho*-hydrogen/equatorial hydrogen interactions that beset the phenyl ‘perpendicular’ conformers in **5**, **7**, **11**, and **13** are replaced by far less severe *ortho*-hydrogen/oxygen interactions. In addition the *ortho*-hydrogens are at similar distances from the oxygens in the ground state as well as the rotational transition state, and this appears to lead to a CH•••O Coulombic attraction for both states.

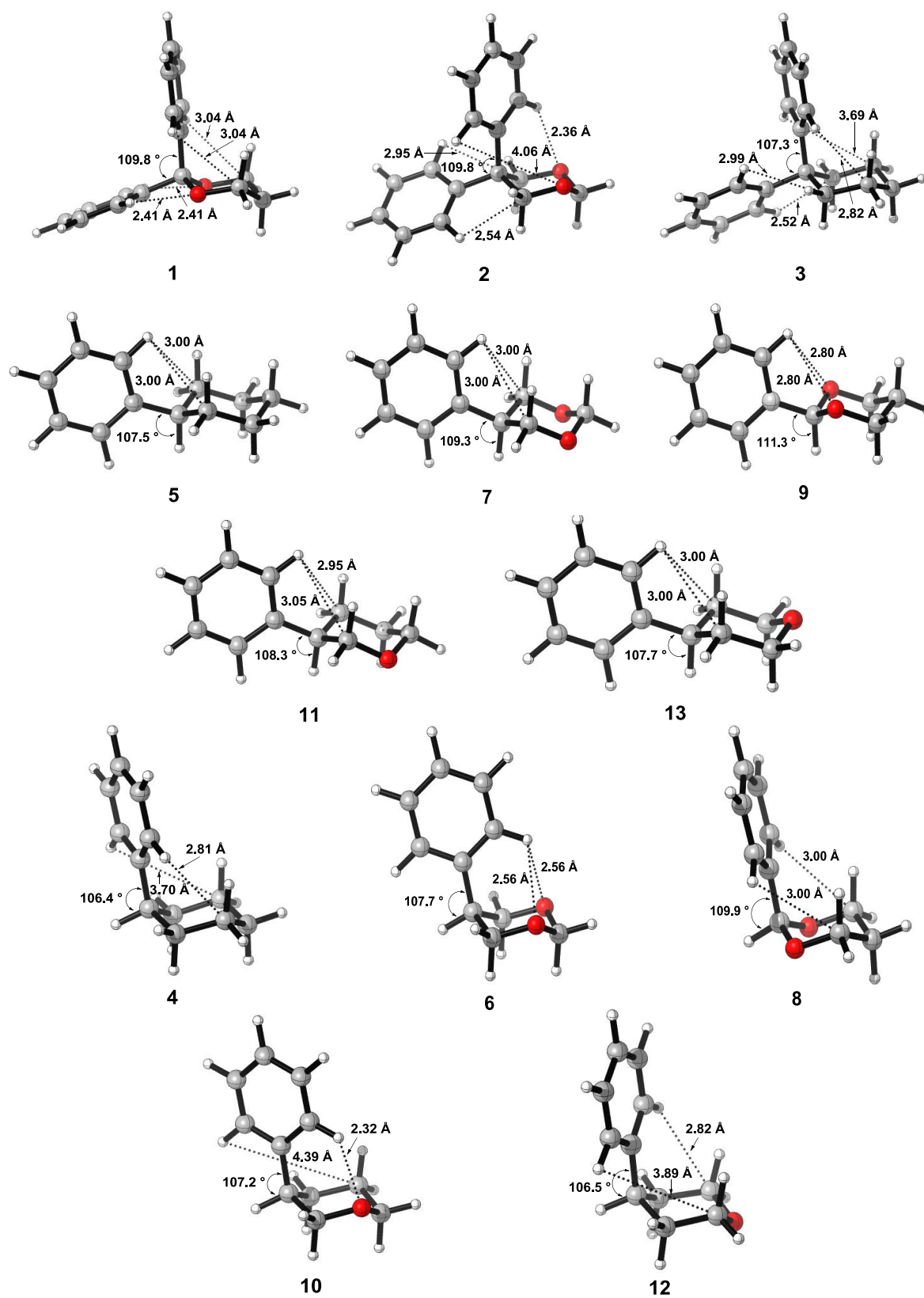


Figure 1-14

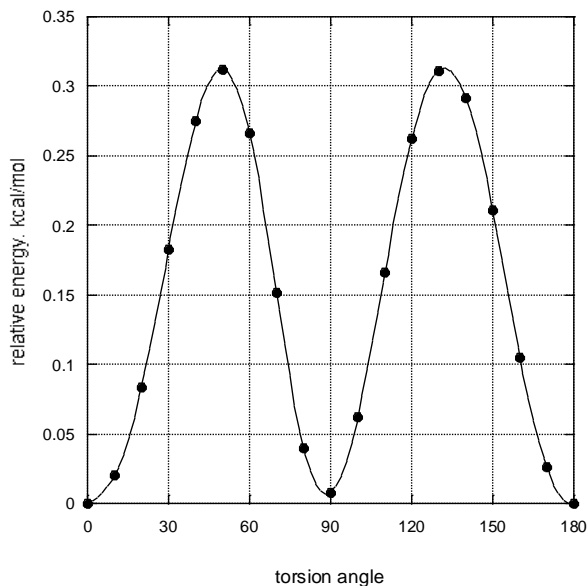


Figure 1-15

The rotameric arrangements of the compounds bearing an axial phenyl provide more variety. The more interesting of these compounds are axial-5-phenyldioxane (**6**) and axial-3-phenyltetrahydropyran (**10**). The first of these compounds is the only axial phenyl compound to adopt a parallel conformation, and it is difficult to think of any interaction that could uniquely favor this other than a Coulombic interaction between an *ortho*-hydrogen of the phenyl and the two oxygens of the ring. Indeed, such an interaction is confirmed by the conformation adopted by axial-3-tetrahydropyran (**10**); the phenyl ring is rotated so that it places an *ortho* hydrogen near the oxygen. There are of course many other interactions present in the axially substituted compound, but these two examples show that the CH \cdots O interaction is of major importance. Compound **8**, axial 2-phenyl-1,3-dioxane, is different from the other axially substituted compounds in having a much larger (7.3 kcal/mol) rotational barrier.

The hydrogens on the phenyl rings have a Hirshfeld charge³⁰ of about 0.042 e³¹ and the oxygens of the 1,3-dioxane and THP have a negative charge of about -0.23 e. The CH \cdots O distance is 2.56 Å in **6** and this leads to a modest Coulombic stabilization (1.2 kcal/mol) that can overcome the usual preference for a perpendicular conformation. There is considerable evidence for CH \cdots O attractive interactions,³² and Coulombic interactions are frequently found in organic compounds.³³

With this in mind, we can reexamine compounds **1**, **2** and **3**. The phenyl groups in **1** adopt a perpendicular conformation whereas in **3** the rings are somewhat twisted. The force leading to the conformation of **1** is probably the CH \cdots O attraction discussed above. In **2**, the phenyl rings are even more twisted than in **3**. Twisting the axial phenyl in **2** facilitates a CH \cdots O stabilizing interaction, and when the axial ring rotates, it allows more freedom for the equatorial ring to rotate toward the orientation found in the equatorial mono-phenyl compounds.

1.4 The Role of CH \cdots O Columbic Interactions in Determining Rotameric Conformations of Phenyl Substituted 1,3-Dioxanes and Tetrahydropyrans³⁴

Some time ago Allinger and Tribble,²⁸ in an early application of the molecular mechanics method, demonstrated that the phenyl ring in equatorial phenylcyclohexane preferentially adopts a rotameric conformation in which the aromatic ring eclipses the benzylic C–H bond (“phenyl parallel” conformation). This arrangement avoids unfavorable steric interaction between the *ortho*-hydrogens of phenyl and the equatorial hydrogens at C(2) and C(6) of the cyclohexane chair. In contrast, axial phenylcyclohexane adopts a “phenyl perpendicular” conformation in which the plane of the aromatic ring is orthogonal to the benzylic C–H bond (and flatside-on to the *syn*-axial hydrogens). Accordingly, the steric interaction in axial phenylcyclohexane is due mainly to compression of the *ortho*-hydrogens of the phenyl ring with the equatorial cyclohexyl hydrogens at C(2) and C(6) and only partly to *syn*-axial repulsion. More recently, we reported the results of a more detailed ab initio study of phenylcyclohexane and 1-methyl-1-phenylcyclohexane that were in accord with the conclusions drawn from the MM1 analysis.^{13c}

It has been tacitly assumed that the rotameric arrangement of a phenyl group in a saturated six-membered heterocycle corresponds, at least qualitatively, to that found in axial and equatorial phenylcyclohexane. As shown below, this is not always the case: attractive Coulombic interactions between the *ortho*-hydrogen of a phenyl ring and an oxygen in a 1,3-dioxane or tetrahydropyran can dramatically alter the preferred rotameric conformation of the aromatic ring.²⁷

In an effort to investigate the potential effect of ring heteroatoms on the rotameric behavior of phenyl-substituted saturated six-membered heterocycles, phenyl-substituted 1,3-dioxanes and tetrahydropyrans were examined and compared to the results found for the corresponding phenylcyclohexanes. As noted above, we have reported a computational study of the latter that found that MP2 is more satisfactory than DFT.^{13c} Therefore, all of the compounds were studied at the MP2/6-311+G* level for the geometry optimizations, the vibrational frequencies and the rotational barrier scans. The effect of internal rotation of the phenyl group in the systems studied leads non-negligible contributions to the free energies of these molecules. These entropic contributions are not of much importance in the present context and, for this reason; we chose to focus on computation of ΔH rather than ΔG . The results of these studies, corrected for differences in zero point energies and thermal corrections to 25 °C, are summarized in Table 1-7 and the computed structures are shown in Figure 1-16.

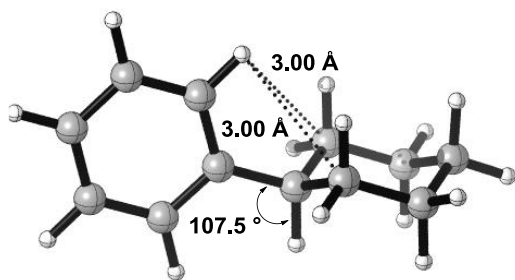
Table 1-7^a

compound	τ^b	μ (D)	ΔH° (298) ^c
ax-phenylcyclohexane (2)	66.2	0.451	3.24
eq-phenylcyclohexane (1)	0.0	0.530	0.00
ax-2-phenyl-1,3-dioxane (4)	87.5	2.460	1.13
eq-2-phenyl-1,3-dioxane (3)	0.0	2.512	0.00
ax-5-phenyl-1,3-dioxane (6)	0.0	2.303	0.83
eq-5-phenyl-1,3-dioxane (5)	0.0	2.512	0.00
ax-2-phenylTHP (8)	100.3	1.584	2.19
eq-2-phenylTHP (7)	27.9	1.877	0.00
ax-3-phenylTHP (10)	38.9	1.774	0.72
eq-3-phenylTHP (9)	3.7	1.667	0.00
ax-4-phenylTHP (12)	60.7	2.303	3.53
eq-4-phenylTHP (11)	0.0	2.512	0.00

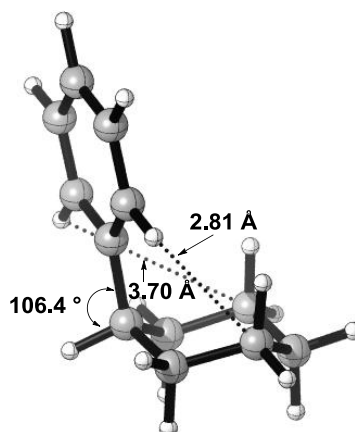
^a MP2/6-311+G* ground state conformational enthalpies, torsional angles and dipole moments ^bH-C-C=C ground state torsion angle; $\tau = 0^\circ$ corresponds to the phenyl parallel conformation, $\tau = 90^\circ$ corresponds to the phenyl perpendicular conformation ^c Kcal/mol

As expected, the compounds with an equatorial phenyl have a lower energy than the corresponding axial substituted isomers. Most of the equatorially substituted compounds (**1**, **3**, **5**, **9** and **11**) display a similar preferred rotameric arrangement of the phenyl group, adopting a "parallel" conformation (τ , H-C-C=C, $\sim 0^\circ$), whereas equatorial 2-phenyltetrahydropyran (**7**) has $\tau = 27.9^\circ$. The twisted conformation adopted by **7** places an ortho-hydrogen of the phenyl in rather close proximity to the ring oxygen of the THP; this aspect is discussed in further detail below. The conformations of the equatorially-substituted compounds (other than **7**) has the benzylic C-H bond eclipsed with the aryl ring. This is largely the result of steric interactions between the ortho-hydrogens of the phenyl group and the equatorial hydrogens of the ring to which it is attached as noted by Allinger and Tribble.²⁸ While most of the equatorially phenyl-substituted molecules have similar structures, there are significant differences in rotational barriers.

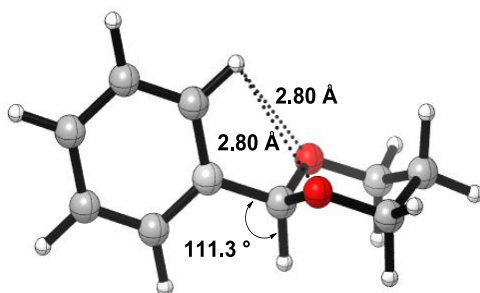
The rotational barriers are of importance to achieving an understanding of the differences in rotameric conformational preferences, particularly for the axially-substituted six-membered rings. The barriers have been studied by carrying out geometry optimizations with the torsion angle between the aryl ring and the benzylic C-H bond stepped at 10° intervals. The rotational profiles, which are shown in Figure 1-17, do not include the effect of differences in zero-point energies. The maxima in each of the rotational profiles were further characterized by geometry optimizations for the higher energy rotamers, displayed in Figure 1-17, to transition states, followed by vibrational frequency calculations and corrections for zero-point energies and thermal energies. These data are summarized in Table 1-8; the ΔE^\ddagger at 0 K (which = ΔH^\ddagger at 0 K) are given along with ΔH^\ddagger at 298 K (25 °C). The relatively large thermal corrections are mainly due to a loss of a vibrational mode on going from the ground state to the transition state. The computed transition state structures are displayed in Figure 1-18. Now, all of the readily obtained information is in hand for studying the conformational preferences.



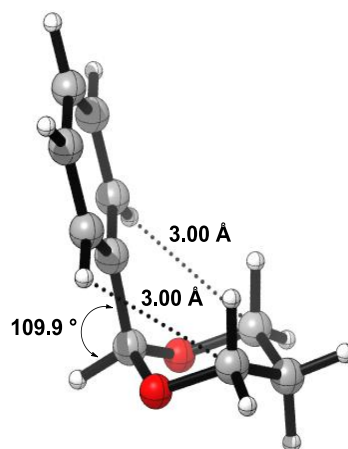
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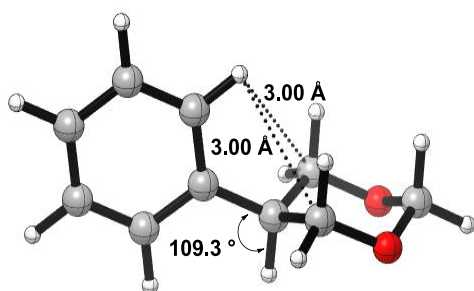
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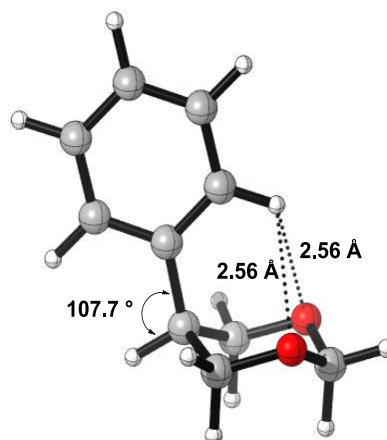
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6

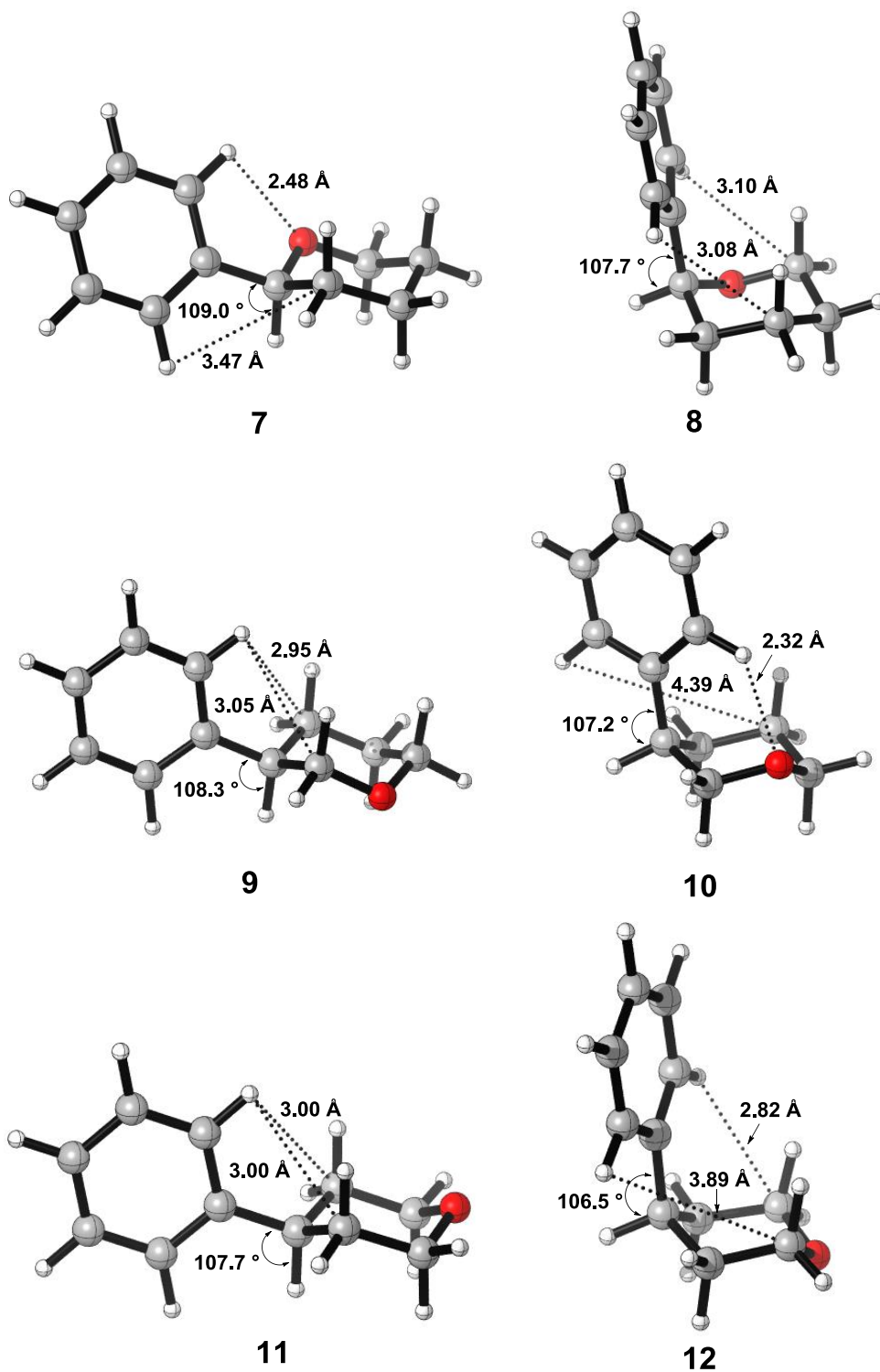
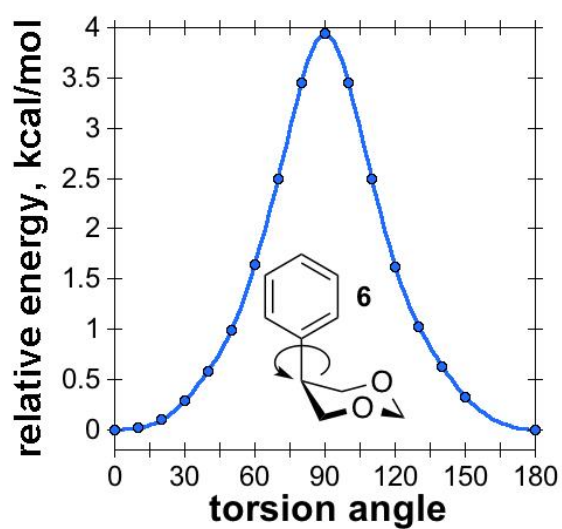
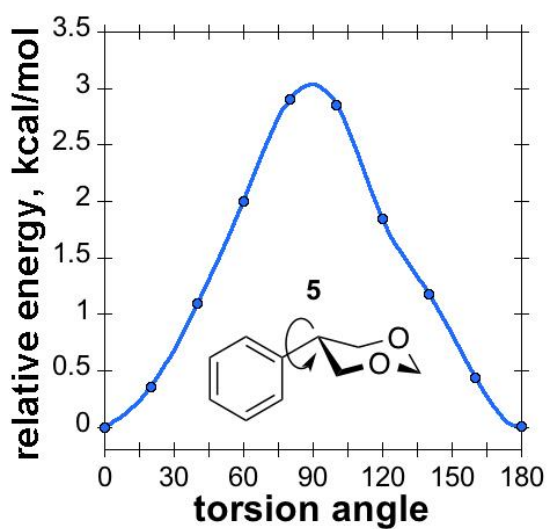
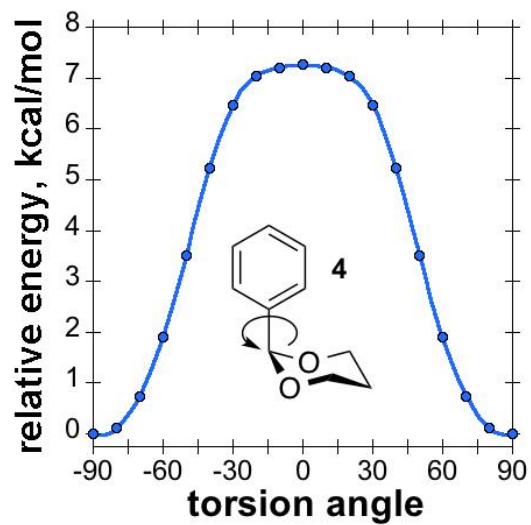
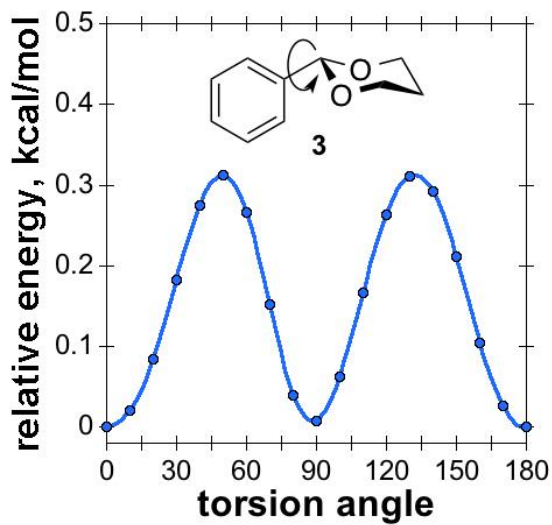
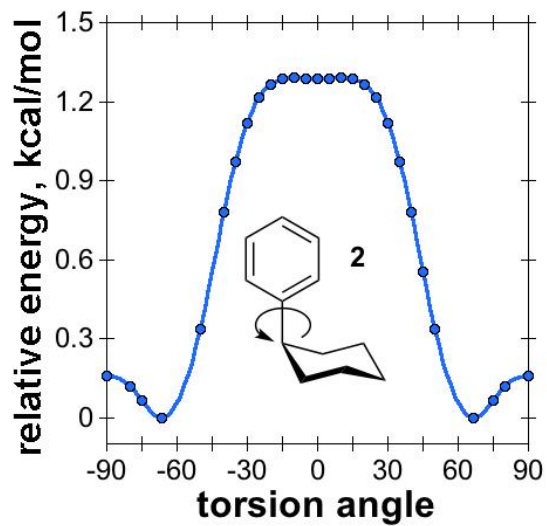
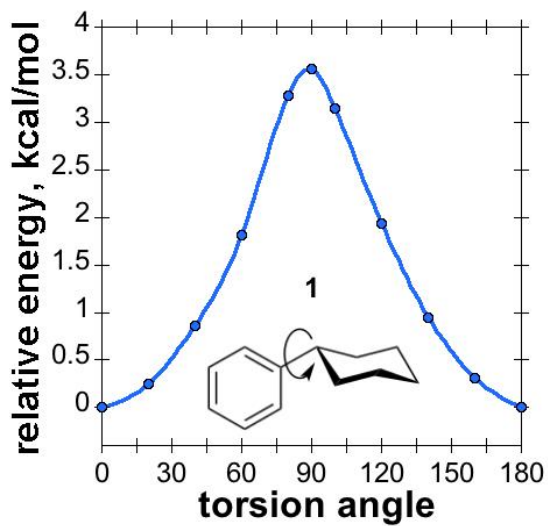


Figure 1-16



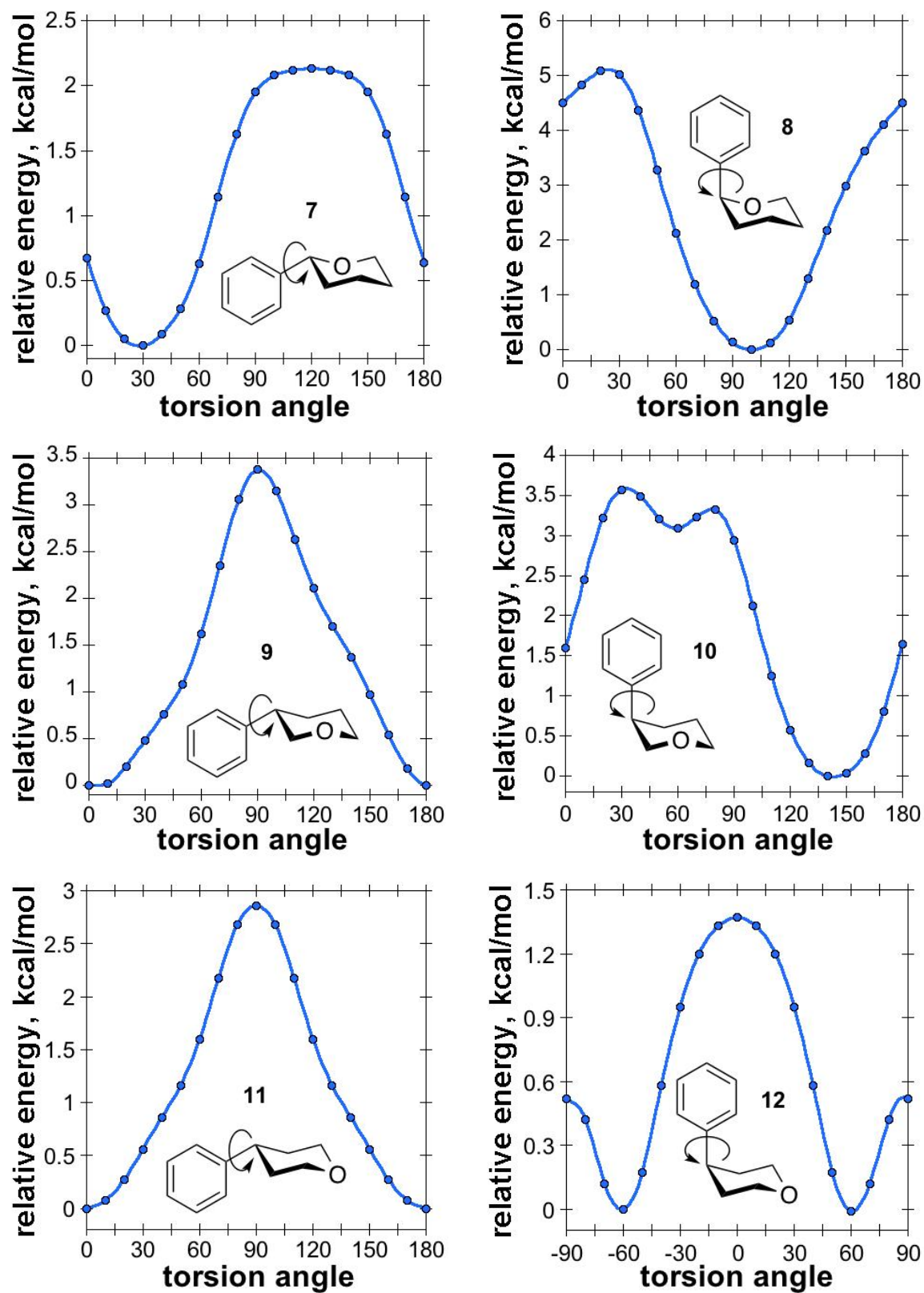


Figure 1-17

The barriers to phenyl rotation in the equatorial phenyl compounds **1**, **5**, **7**, **9** and **11** are similar and largely the result of steric interactions between the *ortho*-hydrogens of the phenyl group and the equatorial hydrogens of the ring to which it is attached. However, equatorial 2-phenyl-1,3-dioxane (**3**) is strikingly different than the other equatorially substituted compounds. The phenyl – C(2) rotational barrier in **3** is only 0.3 kcal/mol with approximately equal energetic minima at $\tau = 0$ and 90° (Figure 1-17). The barrier is reduced even more at 298 K because of the difference in thermal correction for the GS and TS. Indeed, an experimental study found this compound to have a very small barrier; the phenyl is virtually a free-rotor.^{13a–b, 29} This low barrier must be related to the dioxane oxygens since this is the only source of a difference with respect to the other compounds. In **3** the destabilizing *ortho*-hydrogen / equatorial hydrogen interactions that beset the phenyl “perpendicular” conformers in **1**, **5**, **9** and **11** are replaced by far less severe *ortho*-hydrogen / oxygen interactions. In addition, the *ortho*-hydrogens are at small distances from the oxygens at 90° and, as described below, this leads to an attractive CH...O Coulombic attraction.

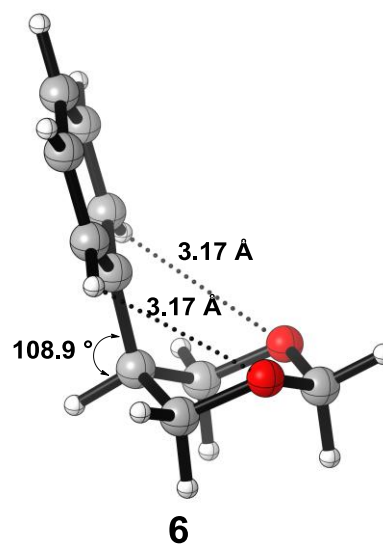
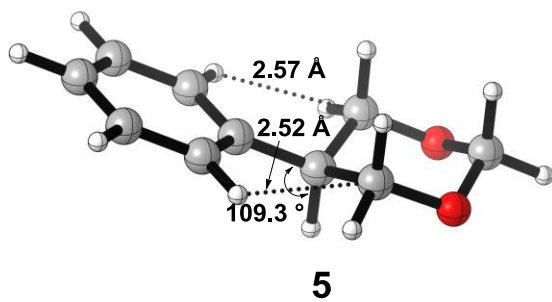
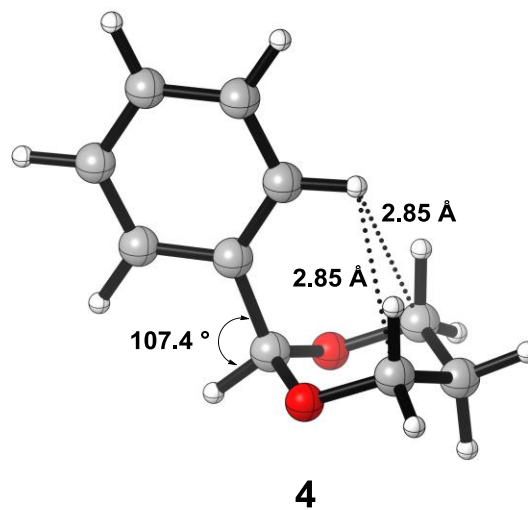
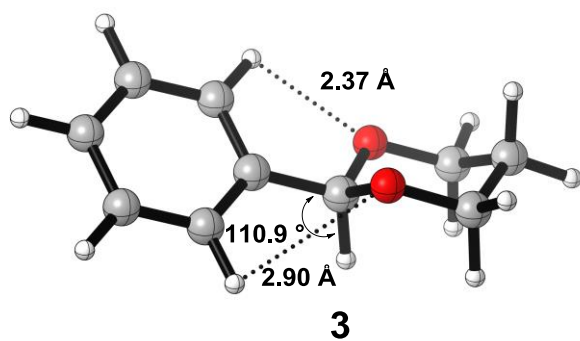
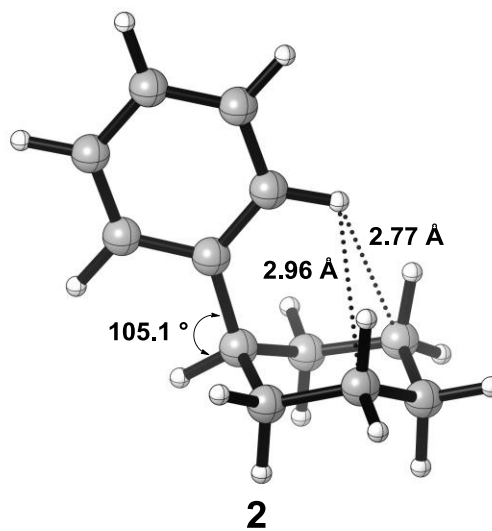
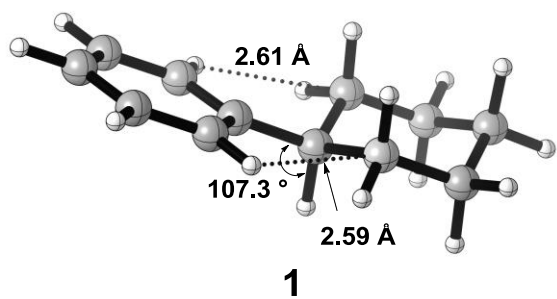
Table 1-8^a

compound	τ ^b	μ (D)	ΔE^\ddagger (0) ^c	ΔH^\ddagger (298) ^c
ax-phenylcyclohexane (2)	10.0	0.437	1.12	0.66
eq-phenylcyclohexane (1)	90.0	0.649	3.73	3.14
ax-2-phenyl-1,3-dioxane (4)	0.0	2.231	7.08	6.68
eq-2-phenyl-1,3-dioxane (3)	47.7	1.793	0.33	−0.26
ax-5-phenyl-1,3-dioxane (6)	90.0	2.331	4.12	3.46
eq-5-phenyl-1,3-dioxane (5)	90.0	1.936	5.01	4.29
ax-2-phenylTHP (8)	24.2	1.793	4.67	4.33
eq-2-phenylTHP (7)	134.6	1.327	2.26	1.67
ax-3-phenylTHP (10)	39.0	1.832	3.50	3.01
eq-3-phenylTHP (9)	90.0	1.614	3.54	2.96
ax-4-phenylTHP (12)	0.0	1.565	1.30	0.85
eq-4-phenylTHP (11)	90.0	1.494	3.03	2.43

^aMP2/6-311+G* transition state energies, torsional angles and dipole moments ^bH-C-C=C ground state torsion angle; $\tau = 0^\circ$ corresponds to the phenyl parallel conformation, $\tau = 90^\circ$ corresponds to the phenyl perpendicular conformation ^c Kcal/mol

The equatorially substituted 2-phenyltetrahydropyran (**7**), with a rotational barrier of 2.3 kcal/mol (Table 1-8), presents a somewhat different situation than the compounds discussed above. The ground state structure of **7** (Figure 1-16 and Table 1-8) displays a torsional angle that is increased from the phenyl parallel arrangement to 27.9°. As noted above, this involves twisting of the phenyl ring to bring an *ortho* hydrogen rather close to the THP oxygen. This behavior is most easily rationalized as resulting from an attractive CH...O Coulombic interaction. One way to test this hypothesis is to examine the charges at the atoms involved in the interaction between the nearby *ortho* hydrogen and the ring oxygen. To this end, the Hirshfeld charges, derived from the electron density distribution, were computed.³⁰ It was found that the *ortho* aryl hydrogen in **7** has a charge of +0.046e, and the oxygen has a charge of -0.225e. The hydrogen charge is quite reasonable: it has been found experimentally that there is very little charge separation in the C-H bonds of methane,³¹ and the increased s-character of the phenyl C-H bonds should lead to a small positive charge on the hydrogens. On this basis, a rough estimate of the Coulombic energy ($E = q_1q_2/r$) associated with the CH...O interaction in **7** at a distance of 2.49 Å is 1.4 kcal/mol.³⁵ Clearly, an attractive interaction of this magnitude could easily lead to the observed torsion angle.

The rotameric arrangements of the compounds bearing an axial phenyl are potentially more interesting than those of the equatorially substituted analogs. A comparison of axial 2-phenyl-1,3-dioxane (**4**) with axial phenylcyclohexane (**2**) finds (Table 1-8) that, whereas **2** has a relatively small rotational barrier ($\Delta E^\ddagger = 1.1$ kcal/mol), **4** has an unusually large barrier of 7.1 kcal/mol. The barrier to rotation of the axial phenyl group in **2** is reduced because there is some repulsion between the *ortho* hydrogens of the phenyl ring and equatorial C(2) hydrogens of the cyclohexane leading to ground-state destabilization of **2**. Conversely, in axial 2-phenyl-1,3-dioxane (**4**), the equatorial C(2) hydrogens present in **2** are replaced with oxygen atoms. Thus, the steric interaction between the *ortho* hydrogens and the equatorial C(2) hydrogens that plague **2** are absent in the dioxane analog. Moreover, the *ortho*-hydrogens of the axial phenyl ring in **4** are close to the dioxane oxygens and this presumably leads to a CH...O attraction. Consequently, in the case of axial 2-phenyl-1,3-dioxane (**4**), the ground-state is stabilized leading to the large barrier to rotation.



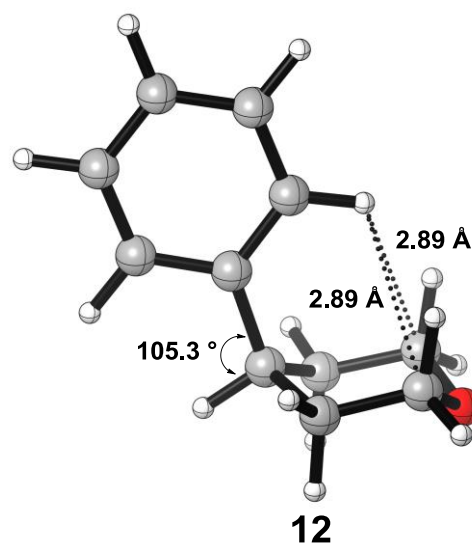
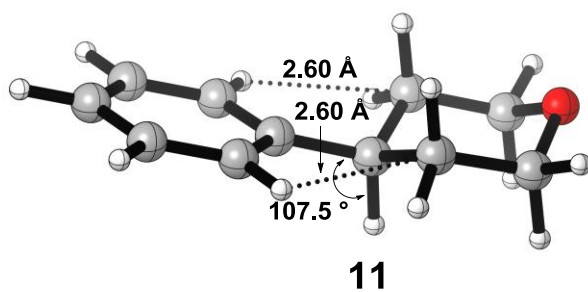
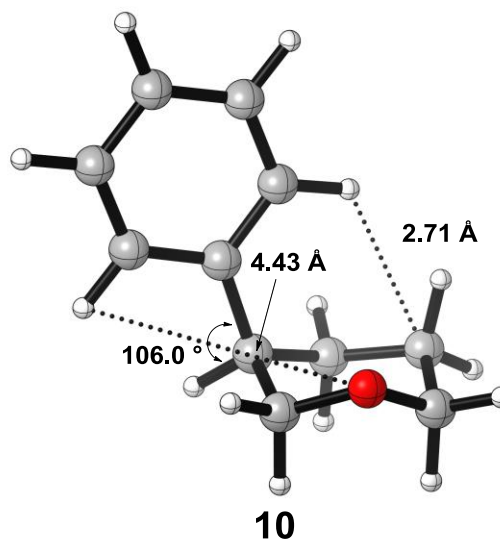
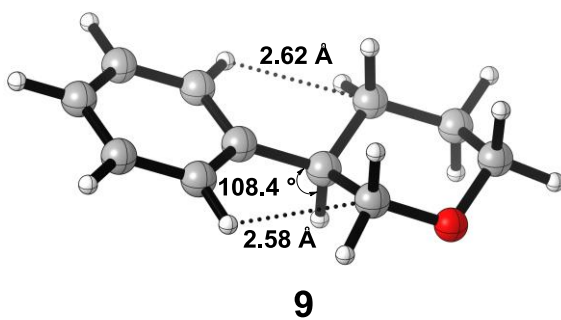
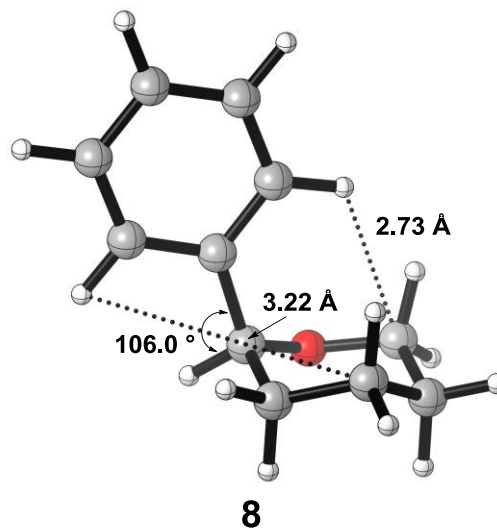
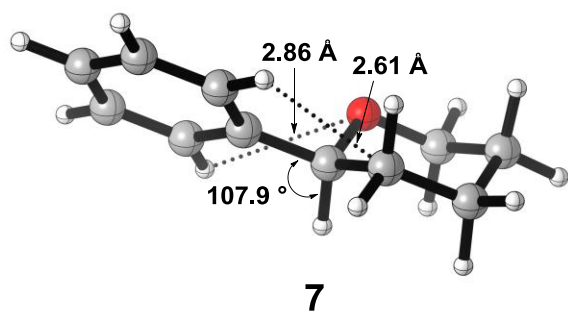


Figure 1-18

The most fascinating of the axially phenyl-substituted compounds are axial 5-phenyl-1,3-dioxane (**6**) and axial 3-phenyltetrahydropyran (**10**). The first of these compounds (**6**) adopts a perfectly parallel conformation (Table 1-7, Figure 1-16) in which the plane of the phenyl ring bisects the 1,3-dioxane ring. To our knowledge, this is the only example of a six-membered saturated ring bearing an axial aryl group in which the aryl ring adopts such a ground state conformation. Indeed, a previous analysis of the conformational behavior of axial 5-phenyl-1,3-dioxane had tacitly assumed that the phenyl would adopt the perpendicular arrangement found in axial phenylcyclohexane.³⁶

It is difficult to envision any interaction that might uniquely favor the phenyl parallel conformation in **6** other than an attractive Coulombic interaction between an *ortho*-hydrogen of the phenyl ring and the 1,3-oxygens of the dioxane at the computed distance of 2.56 Å. This hypothesis was tested computationally by replacing the phenyl group in axial 5-phenyl-1,3-dioxane (**6**) with a 2-pyridyl ring. In axial 5-pyridyl-1,3-dioxane the nitrogen atom will bear a negative charge leading to a repulsive interaction with the negatively charged oxygens of the 1,3-dioxane in the parallel rotamer having the nitrogen neighboring the oxygens. As shown in Figure 1-19, axial 5-pyridyl-1,3-dioxane adopts an approximately perpendicular conformation with the pyridyl ring twisted (τ , N=C–C–H, $\sim 30^\circ$) from a perfectly perpendicular conformation to position the nitrogen close to one of the equatorial hydrogens at C(4) of the dioxane. The maximum energy rotamer is found when the nitrogen of the pyridyl ring is between the two oxygens of the 1,3-dioxane (τ , N=C–C–H, $= 180^\circ$). In the absence of the nitrogen, the energy at $\tau = 180^\circ$ would be close to zero. The calculated barrier of 4.5 kcal/mol is apparently the result of an N \cdots O repulsive interaction. The nitrogen-to-oxygen distance in the least stable conformation of axial 5-pyridyl-1,3-dioxane is 3.21 Å and the O and N Hirshfeld charges are –0.182 and –0.198e, respectively. Consequently, there is a repulsive Coulombic energy of ~ 3.7 kcal/mol per N \cdots O pair or a total of about 7.4 kcal/mol for the maximum energy rotamer having the nitrogen of the pyridyl ring between the two oxygens of the 1,3-dioxane. Considering the approximations in this simple approach, the result is in reasonable agreement with the 4.5 kcal/mol computed rotational barrier.³⁷

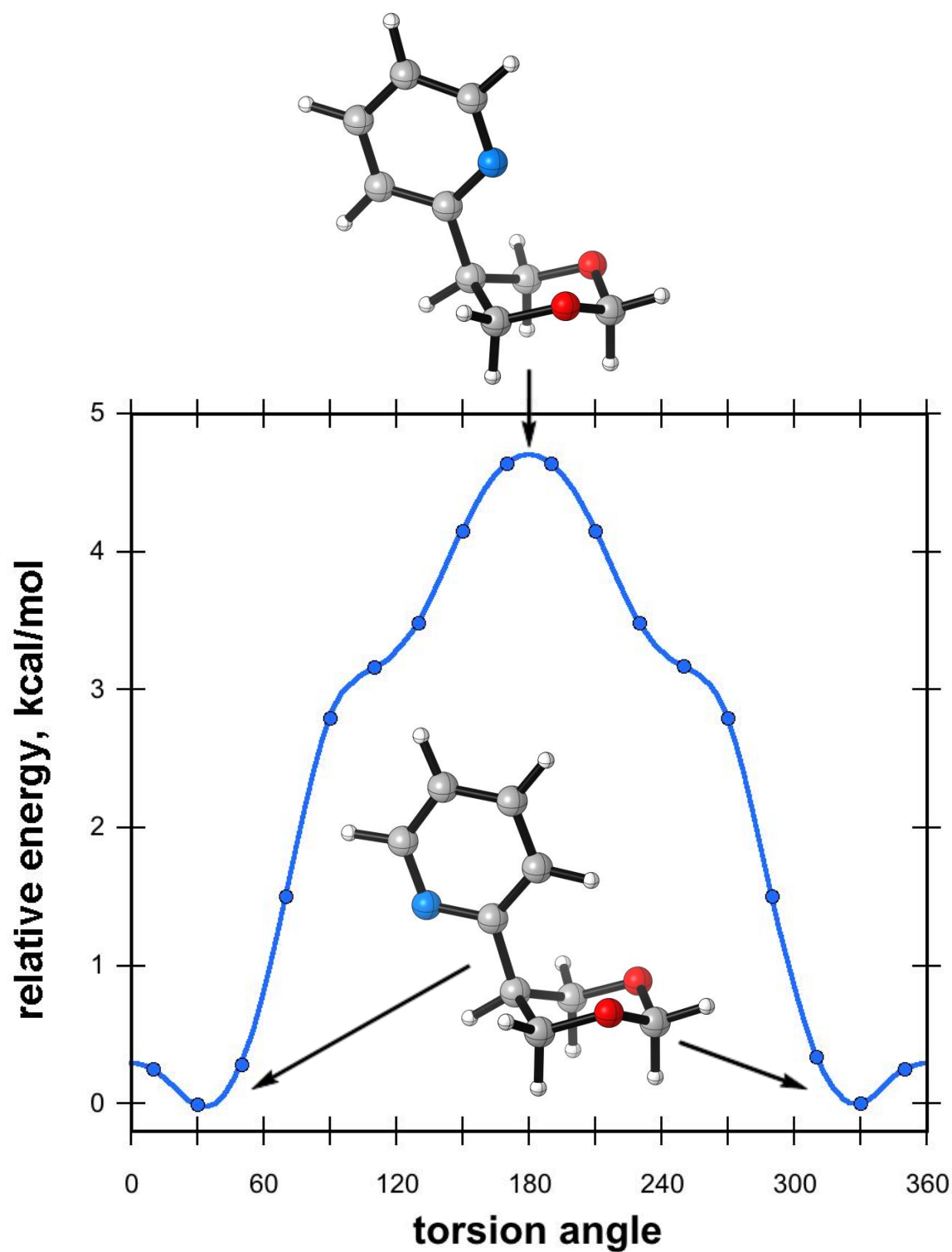


Figure 1-19

An attractive $\text{CH}\cdots\text{O}$ interaction is also found in the conformation adopted by axial-3-phenyltetrahydropyran (**10**). The phenyl ring in **10** is rotated 39° from the phenyl perpendicular

conformation (Table 1-7) so as to place an *ortho*-hydrogen of the phenyl ring near the oxygen of the THP. An estimation of the attractive interaction between the proximate *ortho*-phenyl hydrogen in **10** and the oxygen of the THP ring is easily calculated from the Hirshfeld charges on the *ortho*-hydrogen (+0.038e) and the oxygen (−0.175e) at the computed distance between the hydrogen and the oxygen of 2.32 Å; the Coulombic interaction is attractive by ~1.0 kcal/mol.

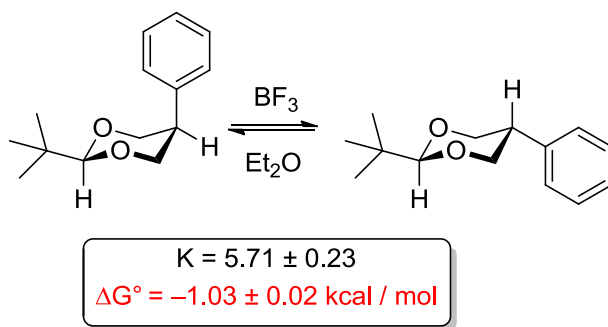
There are of course many other interactions present in these axially substituted compounds, but it appears that an attractive CH...O interaction has a major effect on the rotameric ground-state arrangement of a phenyl group in heteroatom-containing six-membered rings. In short, when possible, an *ortho*-hydrogen in a phenyl ring positions itself to be close to an oxygen atom in the ring to which it is attached.

The phenyl-substituted tetrahydropyrans and 1,3-dioxanes have proven to be very useful in examining weak interactions between C–H and O. Such interactions have been noted previously³⁸ but as far as we can determine, we have observed the first cases in which aryl rings rotate so as to place an aryl hydrogen close to an oxygen. The extra s-character in an aryl C–H bond, vis-à-vis an aliphatic C–H bond, increases the positive charge at the hydrogen leading to a larger attractive Coulombic attraction for a ring oxygen.

1.5 Controlling the Conformational Energy of a Phenyl Group by Tuning the Strength of a Non-Classical CH...O Hydrogen Bond: The Case of 5-Phenyl-1,3-dioxane³⁹

Seminal, fundamental investigations by Eliel's group in the 1960's and 70's of conformational equilibria in substituted 1,3-dioxanes have contributed significantly to current understanding of the nature of steric and electronic effects in saturated heterocyclic systems.⁴⁰ The 1,3-dioxane system has three distinct sites of substitution, each of which displays a unique steric and stereoelectronic environment. Perhaps most importantly, facile acid-catalyzed equilibration of configurationally isomeric 1,3-dioxanes allows for accurate and precise determination of conformational energies.^{4, 15b, 36, 41}

The conformational energy of a phenyl group at the C(5) position of 1,3-dioxane was determined in diethyl ether solvent at room temperature, as illustrated in Scheme 1-2, by Eliel and Knoeber in 1968 by BF_3 - catalyzed equilibration of *cis*- and *trans*-2-*t*-butyl-5-phenyl-1,3-dioxane.^{15a} Significantly, the energy difference, 1.03 ± 0.02 kcal/mol, is substantially lower than the 2.8 kcal/mol conformational energy (A-value) of phenylcyclohexane.⁴² The considerably lower conformational energy of 5-phenyl-1,3-dioxane vis-à-vis phenylcyclohexane was attributed at the time to, “a diminution of the [syn-] axial interactions because, where in cyclohexane there are axial hydrogens in positions 1 and 3, in 1,3-dioxane there are, instead, electron pairs on oxygen”.⁴³ In retrospect, given the results of more recent investigations of the conformational behavior of phenylcyclohexane, this explanation must be reassessed.



Scheme 1-2

The dominant interactions responsible for the sizeable conformational energy of phenylcyclohexane, in which the plane of the axial phenyl ring is perpendicular to the benzylic C–H bond, are now known to be steric repulsion between the equatorial hydrogens at the C(2) and C(6) positions of the cyclohexane ring and the *ortho*-hydrogens of the axial phenyl group.^{13c, 28} In short, *syn*-axial interactions contribute modestly, at best, to the conformational energy of phenylcyclohexane. Clearly, the same repulsive steric interactions present in phenylcyclohexane should beset an axial 5-phenyl group in the 1,3-dioxane system were it also to adopt a rotameric conformation having the plane of the ring perpendicular to the C(5) benzylic hydrogen. Given this background, the question remains: why is the conformational energy of a phenyl group in 5-phenyl-1,3-dioxane only a third as large as that of phenylcyclohexane?

An answer to the question is provided by an unanticipated result of our recent computational investigation of the rotameric conformations of a phenyl ring in a series of axially and equatorially substituted 1,3-dioxanes and tetrahydropyrans.³⁴ As shown below (Figure 1-20), the computed minimum energy rotamer of axial 5-phenyl-1,3-dioxane is one in which the plane of the phenyl ring bisects the 1,3-dioxane ring and is parallel to the benzylic C(5)–H bond. This arrangement positions an *ortho* hydrogen proximate to the two ring oxygens, leading to attractive CH•••O Coulombic interactions.

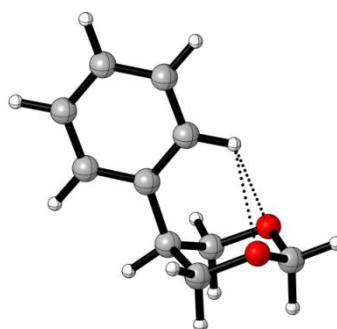


Figure 1-20

To the extent that the computational results comport with reality, we reasoned that the strength of the non-classical CH•••O hydrogen bond⁴⁴ between an *ortho* hydrogen and a ring oxygen in axial 5-phenyl-1,3-dioxane should respond to substituents placed remotely on the phenyl ring: electron-withdrawing groups should strengthen the attractive CH•••O interaction, electron-donating groups should attenuate the interaction. As demonstrated by the results presented below, this is indeed the case.

At the outset of the study, *cis* - (**1**) and *trans*-2-isopropyl-5-phenyl-1,3-dioxane (**2**) were prepared in order to demonstrate, once again,^{15a} that the nature of the 2-alkyl holding group has no effect on the conformational energy of a C(5) substituent determined by direct equilibration of the 1,3-dioxane isomers. A representative series of anancomeric 2-*t*-butyl-5-aryl-1,3-dioxanes (**3** - **14**), depicted in Chart 1-2, were also prepared as illustrated in Scheme 1-3 by acid catalyzed condensation of pivaldehyde with 2-aryl-1,3-propane diols. The diastereoisomeric pairs of 5-aryl-1,3-dioxanes were, with some difficulty, separated chromatographically and fully characterized. The configuration of the individual dioxane isomers follows from the method of preparation of each pair: in each case but one (discussed below) the

thermodynamically more stable trans-isomer (even numbered compounds in Chart 1-2) was the major product of the condensation reactions. Nonetheless, the configurations were further confirmed by ^1H NOESY analysis as detailed in the Experimental Section.

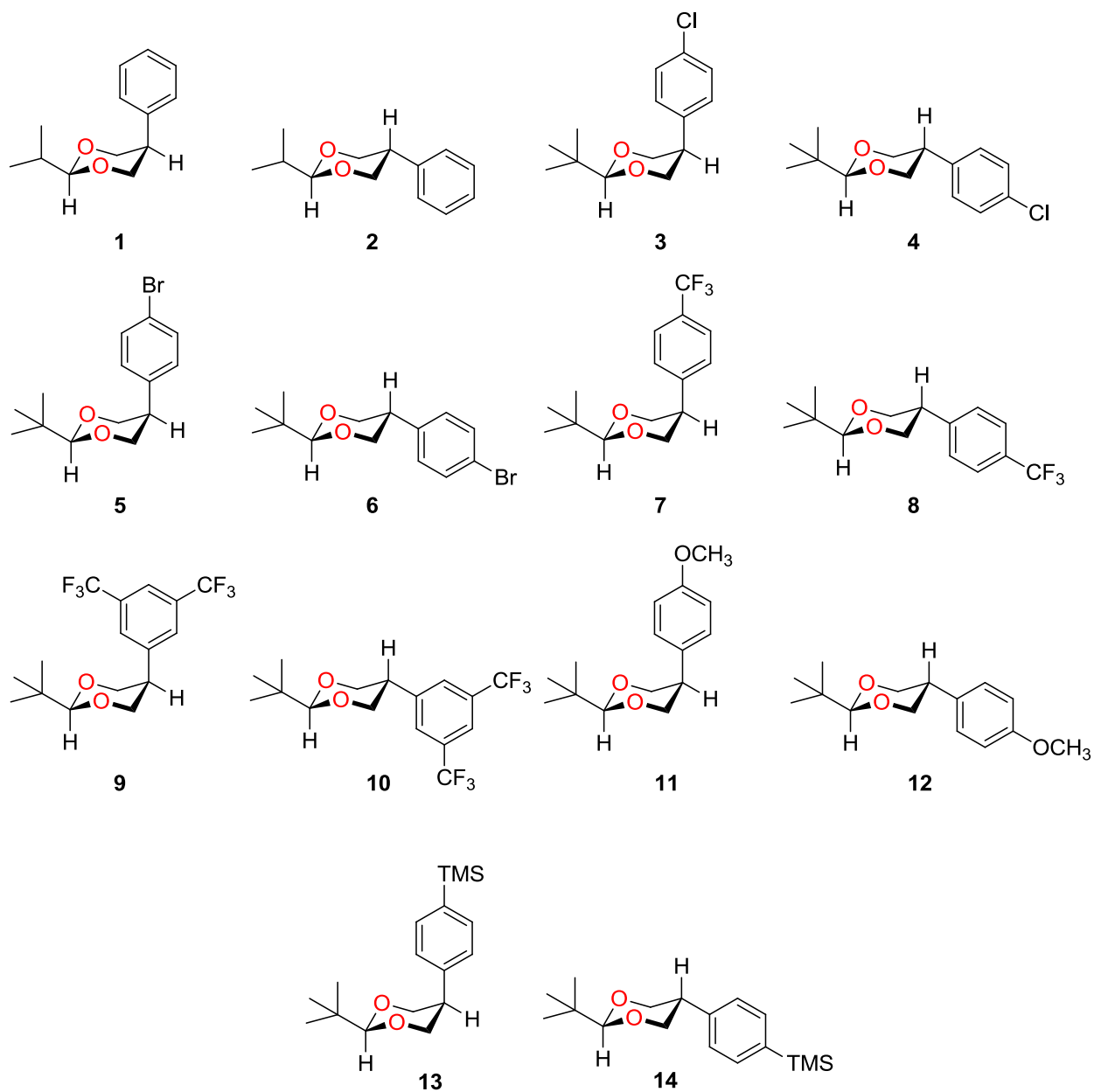
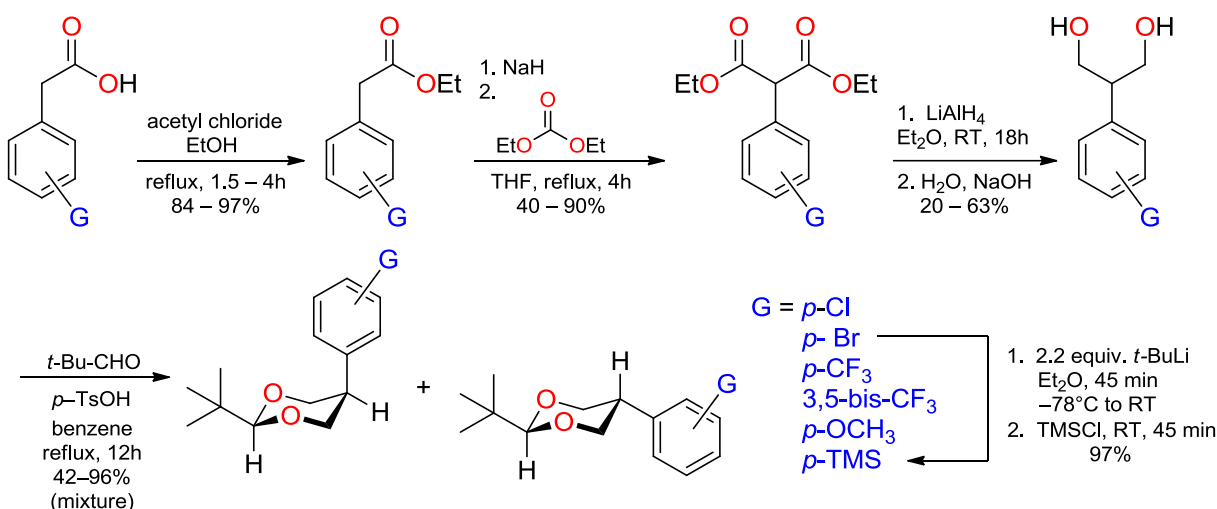


Chart 1-2



Scheme 1-3

An X-ray crystallographic analysis of *cis*-2-*t*-butyl-5-*p*-chlorophenyl-1,3-dioxane (**3**), portrayed in Figure 1-21, corroborates the computational result noted in above. There are two chemically identical, but crystallographically distinct molecules in the asymmetric unit. The axial phenyl ring in both cases adopts a rotameric arrangement in which an ortho hydrogen is in close proximity to one of the dioxane oxygen atoms. The CH...O distances in each of the molecules in the unit cell are virtually identical: 2.41(2) Å and 2.44(2) Å.

Each of the 5-aryl-1,3-dioxane pairs (**1-14**) were equilibrated at room temperature (~ 23 °C) in sealed ampoules under nitrogen as solutions in either cyclohexane or diethyl ether over dry Amberlyst-15 resin. Equilibrium was approached independently from samples of the *cis*-isomer and the *trans*-isomer and, after the solutions were neutralized by shaking with anhydrous K₂CO₃, the area ratio of the isomeric mixture was determined by capillary GC analysis providing baseline separation. It was deemed that equilibrium had been reached when the same area ratios were obtained from initially pure samples of each isomer. Area ratios for each equilibration, which reflect the equilibrium constant for the process, were taken as the average of 5–14 independent determinations from each side, and the free energy difference for the equilibrium was calculated in the normal way: $\Delta G^\circ = -RT \ln K$. The results of these studies are summarized in Table 1-9.

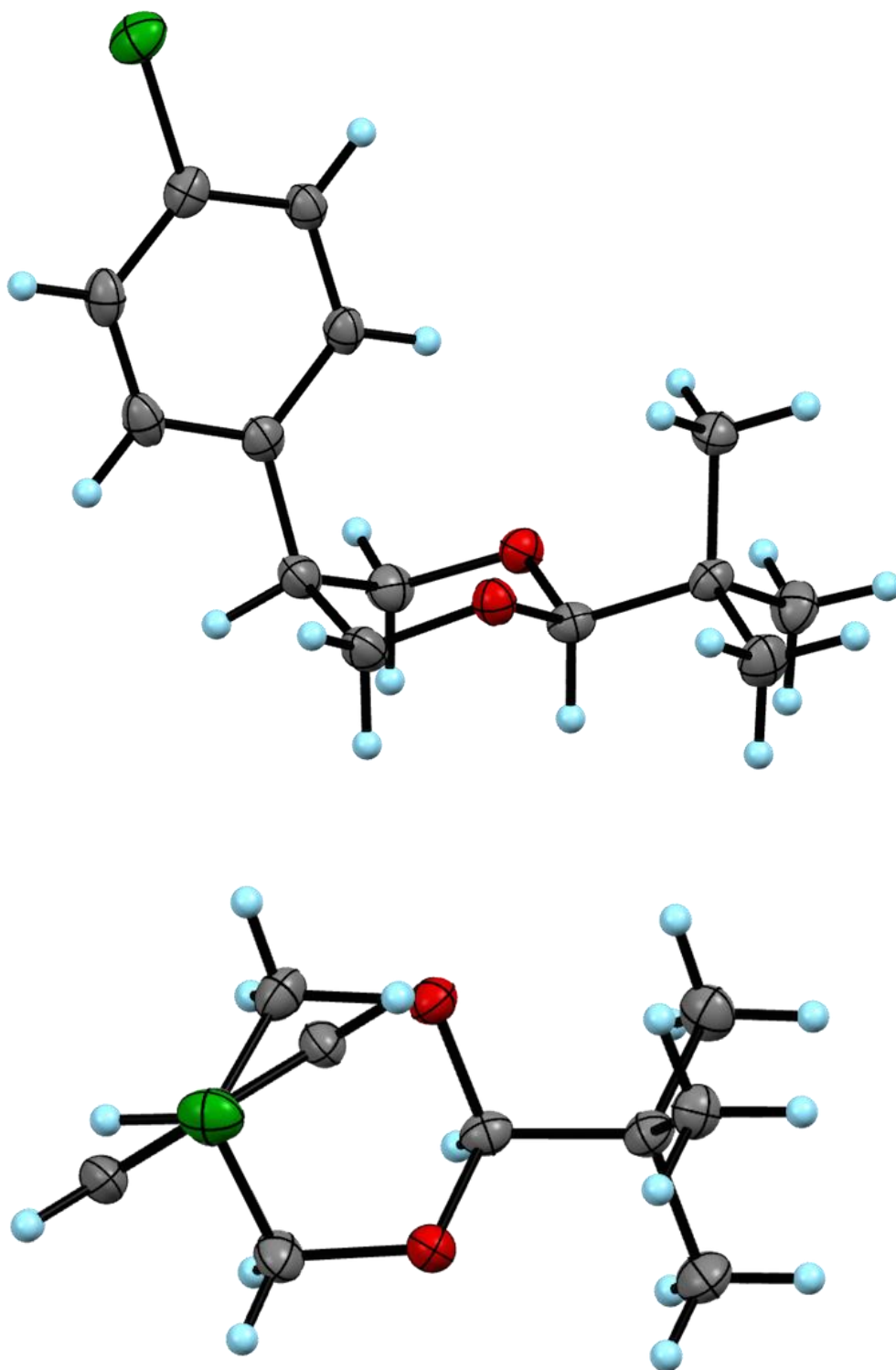


Figure 1-21⁴⁵

Table 1-9

entry	dioxanes	solvent	K	ΔG° (kcal/mol)
1		C_6H_{12}	5.71 ± 0.05	-1.03 ± 0.01
2		Et_2O	6.09 ± 0.07	-1.06 ± 0.01
3		C_6H_{12}	3.19 ± 0.07	-0.68 ± 0.01
4		Et_2O	3.25 ± 0.07	-0.69 ± 0.01
5		C_6H_{12}	3.06 ± 0.01	-0.66 ± 0.01
6		Et_2O	3.19 ± 0.01	-0.68 ± 0.01
7		C_6H_{12}	2.31 ± 0.02	-0.49 ± 0.01
8		Et_2O	3.10 ± 0.01	-0.67 ± 0.01
9		C_6H_{12}	0.63 ± 0.01	$+0.27 \pm 0.01$
10		CH_3CN^b	0.68 ± 0.01	$+0.22 \pm 0.01$
11		C_6H_{12}	6.35 ± 0.02	-1.09 ± 0.01
12		Et_2O	5.73 ± 0.04	-1.03 ± 0.01
13		C_6H_{12}	7.17 ± 0.12	-1.16 ± 0.02
14		Et_2O	6.70 ± 0.14	-1.12 ± 0.01

^aDetermined at room temperature: errors in K are propagated standard deviations; the errors in ΔG° are estimated errors that are larger than the propagated standard deviation to account for an assumed GC response ratio of 1.0 for a given pair of isomers. ^bDuring the slow equilibration of **9** and **10** in Et_2O partial decomposition of the dioxanes to unidentified products was observed and, for this reason, the data for this experiment is not reported.

As expected, the conformational energy of 5-phenyl-1,3-dioxane in diethyl ether solvent determined by equilibration of compounds **1** and **2** having a 2-isopropyl holding group (−1.06 kcal/mol; Table 1-9, entry 2) is identical, within combined experimental error, to that reported by Eliel and Knoeber from equilibration of 2-*t*-butyl-5-phenyl-1,3-dioxane (−1.03 kcal/mol).^{15a} The effect of solvent on the conformational energies of the 5-aryl groups are, on the whole, rather minimal: for a given pair of isomers, the difference in ΔG° is on the order of 0.01 – 0.17 kcal/mol. The more significant conclusion to be drawn from the results is that substituents on the phenyl ring, as remote as the *para* position, affect the conformational energy of a phenyl group.

Cursory inspection of the data presented in Table 1-9 demonstrates that electron-withdrawing substituents (*p*-Cl, *p*-Br, *p*-CF₃, and 3,5-bis-CF₃) stabilize the *cis*-isomer while electron-donating groups (*p*-OMe and *p*-TMS) have a destabilizing effect. Remarkably and unexpectedly, a 3,5-bis-CF₃ phenyl group actually displays a pronounced preference for the axial orientation in both cyclohexane and acetonitrile (Table 1-9, entries 9 and 10). To our knowledge, this is an unprecedented result.

The etiology of the effect of substituents on the strength of the CH•••O hydrogen bond and, hence, the conformational energy of a 5-phenyl-1,3-dioxane is very likely electrostatic. A Hammett plot of the experimental ΔG° values in cyclohexane solution from Table 1 versus σ_m constants,⁴⁶ derived from the pK_a's of substituted benzoic acids, is shown in Figure 1-22. There is a good linear correlation ($r = 0.98$) having a slope (ρ) of +1.5. In this connection, it might be noted that *para*-substituents are *meta* with respect to the *ortho* hydrogen of the phenyl ring that interacts with a ring oxygen. The linear correlation strongly suggests that the effect of substituents on the conformational energy of a 5-phenyl-1,3-dioxane has the same origin as the effect of those substituents on the acidity of benzoic acid: an inductive, electrostatic phenomenon. The picture that emerges is one in which electron-withdrawing substituents render the *ortho* hydrogens of the axial C(5) phenyl group more positive thus increasing the attractive CH•••O hydrogen bond of that hydrogen with an oxygen of the 1,3-dioxane.

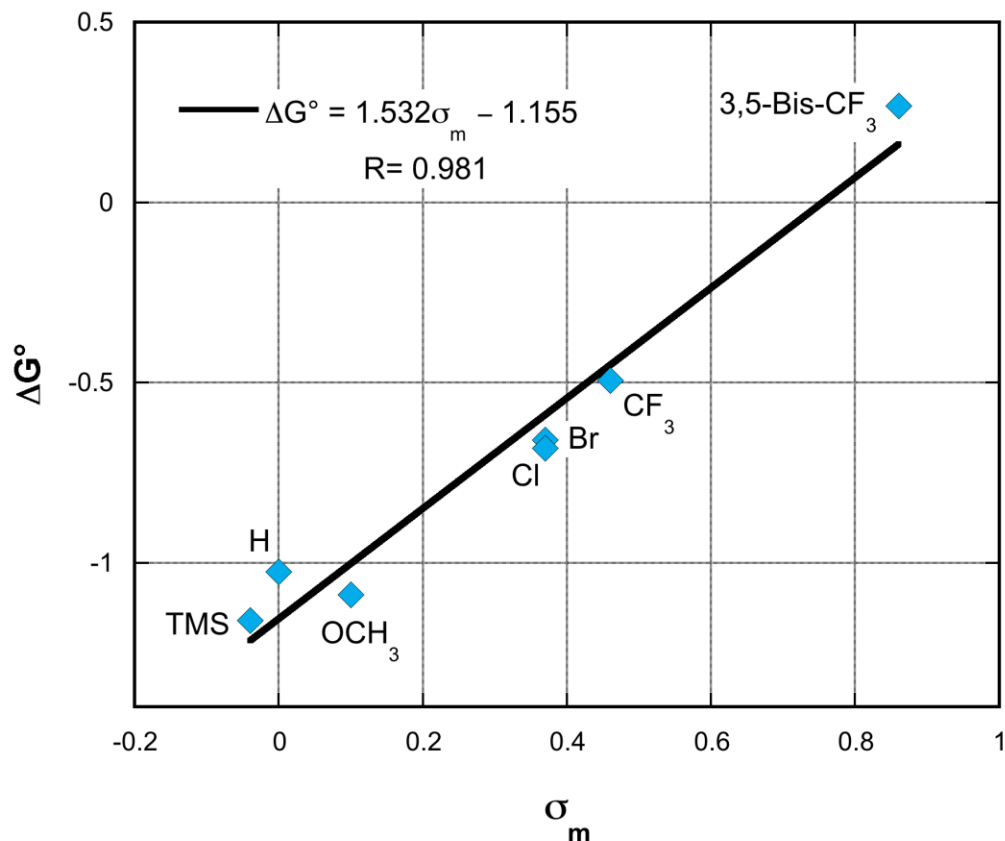
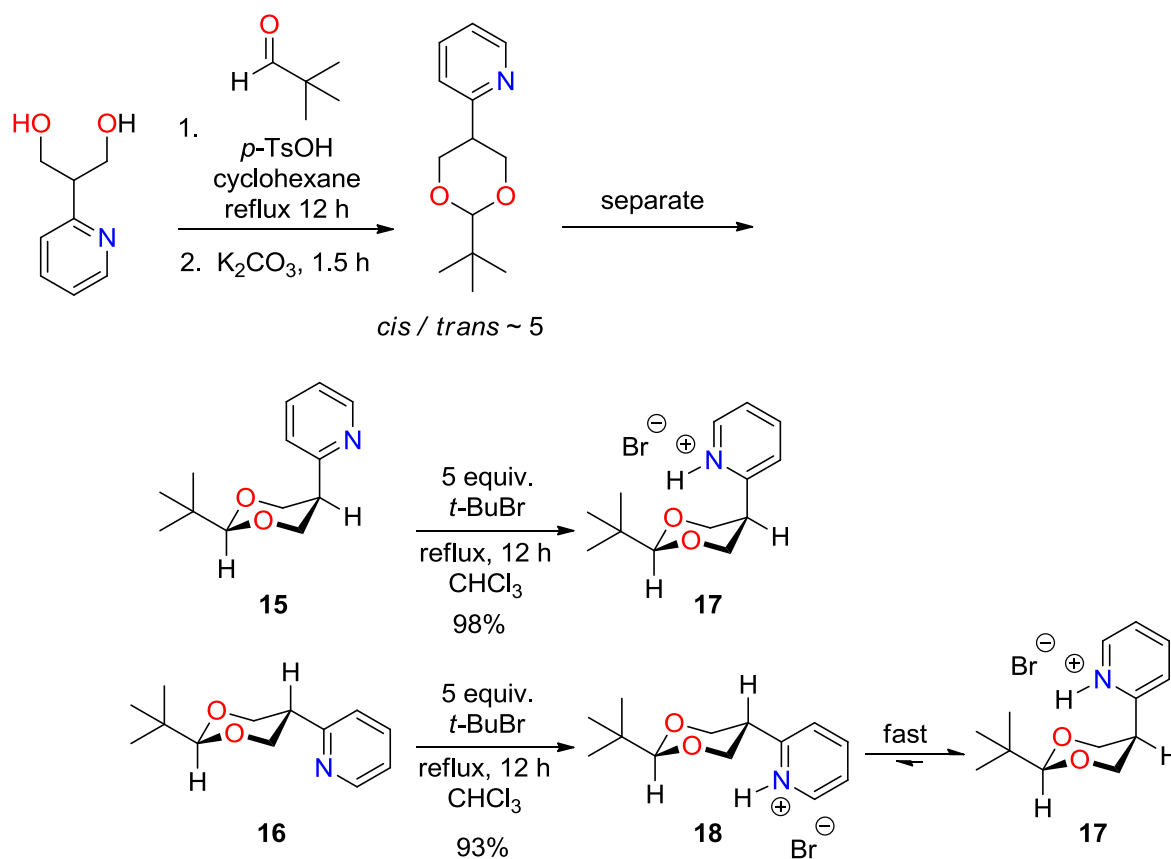


Figure 1-22⁴⁷

This conclusion is further reinforced by the behavior of *cis*-2-*t*-butyl-5-(2-pyridyl)-1,3-dioxane (**15**) and *trans*-2-*t*-butyl-5-(2-pyridyl)-1,3-dioxane (**16**) as well as that of their corresponding pyridinium bromide salts, **17** and **18**. As illustrated in Scheme 1-4, acid-catalyzed condensation of 2-(2-pyridyl)-1,3-propanediol with pivaldehyde gave a mixture of the salts of **15** and **16** containing a preponderance of the salt of the *cis*-isomer (**15**). Neutralization of the reaction mixture and separation of the free amines afforded pure, crystalline *cis*-2-*t*-butyl-5-(2-pyridyl)-1,3-dioxane (**15**): the X-ray structure of this material is shown in Figure 1-23. The molecule adopts a rotameric conformation in which the pyridyl ring very nearly eclipses the C(4)–C(5) bond of the dioxane. The torsion angle made by the pyridyl ring and C(4)–C(5) bond is 7.51(12)°, and positions the nitrogen atom away from the ring oxygens.

Each of the free amines was converted to a pyridinium bromide in high yield under neutral conditions by reaction with *t*-BuBr in chloroform solution (Scheme 1-4).⁴⁸ The *cis*-salt (**17**) is quite stable

both as a solid and in chloroform solution; the *trans*-diastereoisomer, **18**, rapidly isomerizes to **17** particularly in solution. Apparently, the acidic hydrobromide catalyzes equilibration of **17** to **18**. At what we assume to be equilibrium, there is less **18** present than can be detected by ^1H NMR and we estimate that the ΔG° (**17** \rightleftharpoons **18**) exceeds 4.0 kcal/mol. Clearly, the classical hydrogen bond that presumably stabilizes the axial salt (**17**) is an extreme manifestation of the equivalent electrostatic $\text{CH}\cdots\text{O}$ interaction responsible for the effect of remote substituents on the conformational energy of 5-phenyl-1,3-dioxanes.



Scheme 1-4

X-ray crystallographic analysis of compound **17** revealed an interesting result. The protonated pyridyl ring of compound **17** is expected to form a strong H-bond to the ring oxygens, particularly in solution, as the experimentally measured free energy difference (**17** \rightleftharpoons **18**) is > 4 kcal/mol in CDCl_3 solvent. To our surprise, in the solid state, **17** adopts a rotameric conformation similar to that of the free pyridyl ring (**15**); one which eclipses the C(4)–C(5) bond of the dioxane (Figure 1-24).

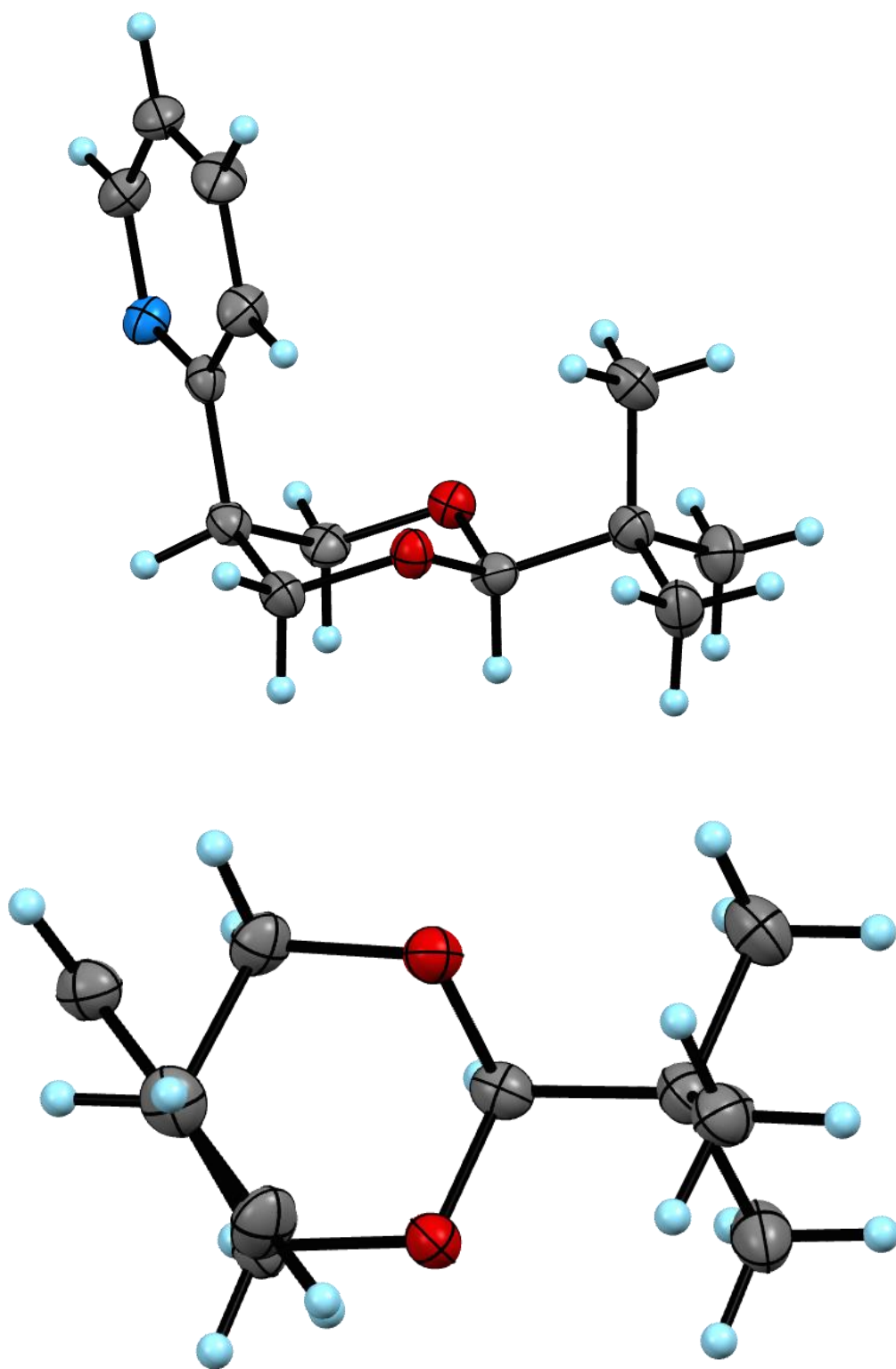


Figure 1-23⁴⁹

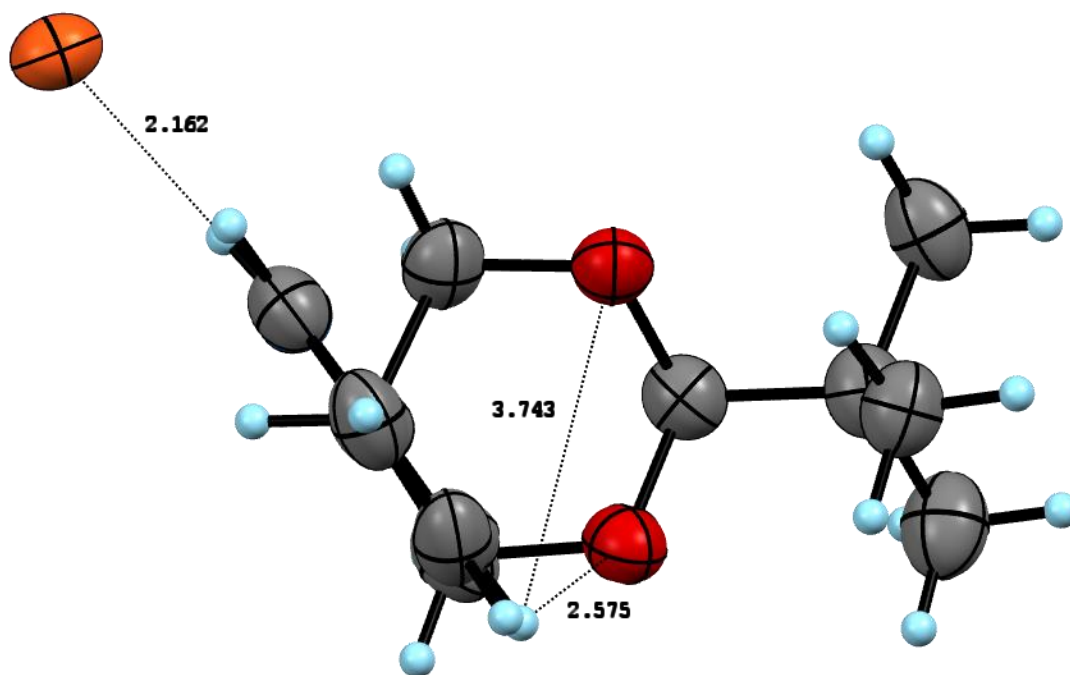
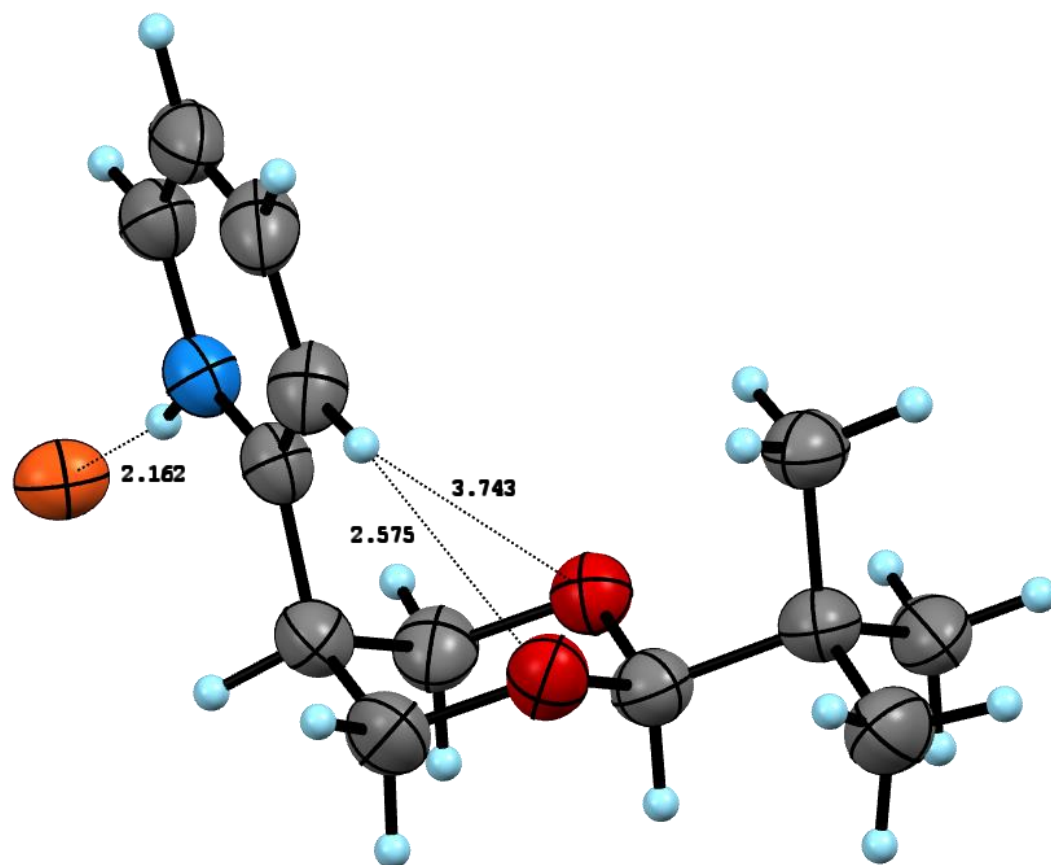


Figure 1-24

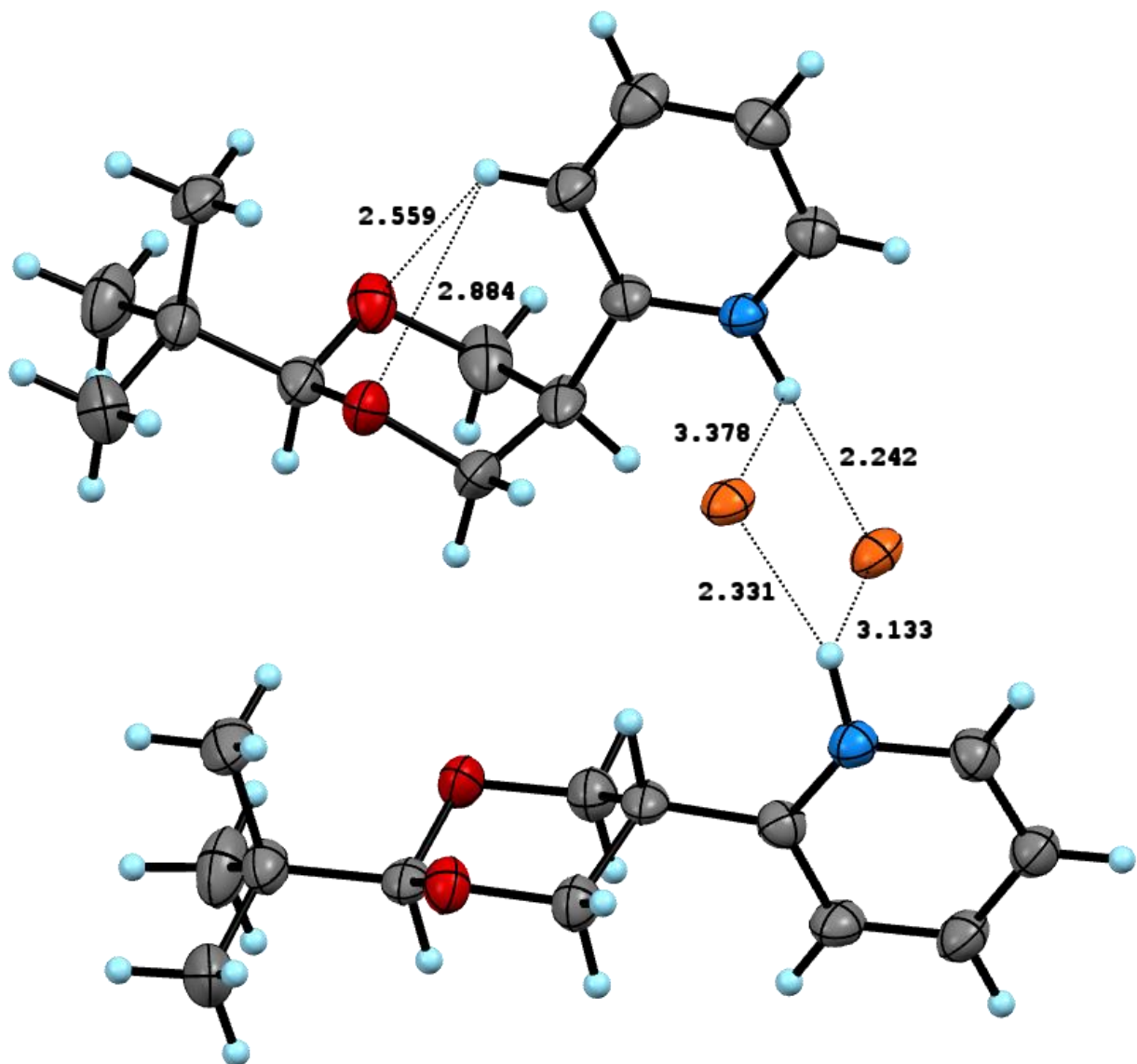


Figure 1-25

. The torsion angle made by the pyridyl ring and C(4)–C(5) bond is $2.11(5)^\circ$, and positions the N–H bond in an orientation that is away from 1,3-dioxane ring, as shown in Figure 1-24. The origin of this unexpected result most certainly arises due to crystal packing forces. The pyridyl N–H hydrogen participates in a strong hydrogen bond with the bromide counterion as shown in Figure 1-24. This behavior is further reinforced by the X-ray crystal structure illustrated in Figure 1-25, wherein molecules **17** and **18** co-crystallize within a single unit cell. The two molecules stack slightly off-center positioning the N–H of each pyridyl ring between two bromine ions. There are four classical hydrogen bonds (N–

H•••Br) displayed within the X-ray crystal structure; two intramolecular strongly covalent H-bonds [2.42(2)Å, **17**; 2.33(1)Å, **18**] and two moderate-to-weak “electrostatic” intermolecular H-bonds [3.37(8)Å, **17**; 3.13(3)Å, **18**].⁵⁰ Additionally, the hydrogen at C(6) of the pyridinium salt is more positive than is the corresponding hydrogen in the parent 2-pyridyl ring.

Secondary to the traditional H-bonding observed, a favorable intramolecular CH•••O interaction between the C(6) hydrogen of the pyridinium salt and the ring oxygens results in a rotation of the pyridinium ring so as to present the C(6)–H to a ring oxygen. The H-C-C=C torsion angle (τ) of the pyridinium ring in the solid state structure is 76.0(1)°, where $\tau = 0^\circ$ corresponds to the parallel conformation and $\tau = 90^\circ$ corresponds to the perpendicular conformation. This non-classical CH•••O hydrogen bond in **17** is 2.55(9) Å between a ring oxygen and the C(6)–H of the pyridinium ring and 2.88(4) Å between the other ring oxygen and the C(6)–H of the pyridinium ring. Such an interaction is characteristic of a “moderate, mostly electrostatic” hydrogen bond based on the interatomic distances.⁵⁰

Before consideration of the results of DFT calculations, described below, that support this conclusion, it is important to note that the entropy contribution to the ΔG° in these systems is negligible. The results of a study of the effect of temperature on the acid-catalyzed equilibrium of between *cis*-2-isopropyl-1,3-dioxane (**1**) and its *trans*-isomer (**2**) in cyclohexane solution are summarized in Table 1-10.

Table 1-10

entry	temp, °C	K	ΔG° (kcal/mol)
1	39.8	5.58 ± 0.04	-1.07 ± 0.01
2	56.1	5.14 ± 0.04	-1.07 ± 0.01
3	66.0	4.81 ± 0.04	-1.06 ± 0.01
4	77.1	4.69 ± 0.04	-1.08 ± 0.01

A van't Hoff plot, $\ln K$ vs T^{-1} , of the equilibrium data, having a correlation coefficient of $r = 0.99$, is shown in Figure 1-26. The slope of the plot is $\Delta H^\circ / R$, where ΔH° is the conformational enthalpy difference between the isomers and the intercept is $\Delta S^\circ / R$, where ΔS° is the conformational entropy

difference. The slope of the plot leads to $\Delta H^\circ = -1.06 \pm 0.06$ kcal/mol and the intercept gives $\Delta S^\circ = +0.03 \pm 0.09$ eu. The results demonstrate that the entropy contribution to ΔG° is insignificant.

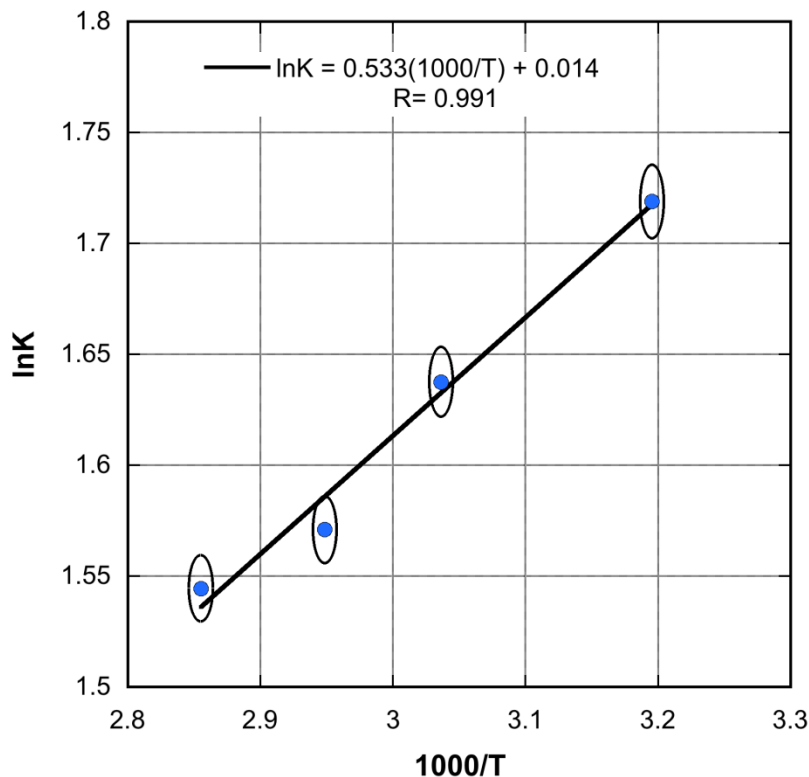


Figure 1-26

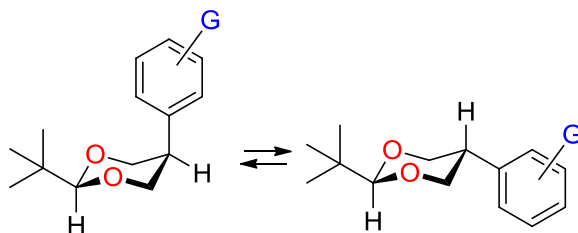
In an effort to achieve further insight into the origin of the effect of aryl substituents on the conformational energy of 5-aryl-1,3-dioxanes (Table 1-9), the 2-*t*-butyl-5-aryl-1,3-dioxanes were explored using density functional theory calculations at the B3LYP/6-311+G* level¹⁹ using tight convergence criteria (opt = verytight, int = ultrafine) for both the optimizations and for calculation of thermal corrections; all of the following data are for 298 K. Details of the calculations may be found in the Experimental Section. The 2-*t*-butyl-5-aryl-1,3-dioxanes have many relatively uncertain low frequencies and the correction from 0 K, as in the DFT calculations, to 298 K is more reliable for ΔH° than for ΔG° ; the former is used in the following discussion. In any event, as demonstrated above, the entropy contribution to ΔG° is essentially zero.

Table 1-11 summarizes the computed substituent effects on the conformational enthalpies ($\Delta\Delta H^\circ$), corrected for differences in zero-point energies and thermal corrections to 25 °C, with the experimental substituent effects ($\Delta\Delta G^\circ$ from Table 1-9). Overall, there is a good correspondence between the experimental and calculated values.

Since we are interested primarily on the effect aryl substituents may have on the strength of the interaction between the proximate *ortho*-hydrogen of an axial phenyl ring with an oxygen of the 1,3-dioxane, it was of interest to explore the charges on the atoms involved in this electrostatic interaction. The calculation of charge distribution within a molecule is fraught with difficulty; such quantities are not well defined. We have chosen to use Hirshfeld charges derived from the electron density distributions.³⁰ The effect of substituents on the charges at both the *ortho*-hydrogen of the phenyl ring and the dioxane oxygen with which it interacts are summarized in Table 1-11. Not surprisingly, the positive charge on the *ortho*-hydrogen increases as the substituent become more electron-withdrawing and decreases in the case of an electron-donating TMS substituent. Qualitatively, the Coulombic energy associated with these intramolecular electrostatic CH \cdots O interactions accounts nicely for the effect of remote aryl substituents on the conformational energy of 5-phenyl-1,3-dioxane. Beyond that, as we have noted previously,³⁴ it would not be prudent to attempt to quantitate the effect by summation of Coulombic energies ($E = q_1q_2/r_{12}$) between the non-bonded atoms because, as demonstrated by Kirkwood and Westheimer, simple two-center calculated Coulombic energies in molecules are attenuated by electric fields associated with the bonds in a molecule.^{26a-b}

In agreement with the results of a recent computational study,³⁴ the minimum energy rotameric conformation of an axial 5-phenyl-1,3-dioxane has been demonstrated to one that positions the aryl ring such that an *ortho*-hydrogen is in close proximity to one of the dioxane ring oxygens (Figure 1-20). The results described above demonstrate that the strength of this non-classical CH \cdots O hydrogen bond may be tuned in response to the electron-withdrawing or electron-donating ability of substituents positioned remotely on the aryl ring.

Table 1-11



G	$\Delta\Delta G^\circ$, from Table 1 ^a relative to G=H	calc $\Delta\Delta H^\circ$ relative to G=H	q (H) ^b , e	q (O) ^c , e
H	0.00	0.00	0.0432	-0.1800
<i>p</i> -Cl	0.35	0.36	0.0472	-0.1760
<i>p</i> -Br	0.37	0.43	0.0476	-0.1636
<i>p</i> -CF ₃	0.54	0.65	0.0471	-0.1633
3,5-bisCF ₃	1.30	1.26	0.0509	-0.1648
<i>p</i> -OMe	-0.06	-0.09	0.0452	-0.1639
<i>p</i> -TMS	0.13	0.06	0.0428	-0.1636

^a In cyclohexane solution ^bHirshfeld charge on *ortho*-hydrogen proximate to ring oxygen

^c Hirshfeld charge of ring oxygen closest to *ortho*-hydrogen

Acid-catalyzed equilibration of a representative series of anancomeric 2-*t*-butyl-5-aryl-1,3-dioxane isomers (Table 1-9) reveals that substituents on the phenyl ring affect the conformational energy of a 5-phenyl-1,3-dioxane in a predictable and quite reasonable way: electron-withdrawing substituents decrease the conformational energy of the phenyl group while electron-donating substituents increase the conformational energy of the group. Moreover, the effect of substituents on the conformational energy of a 5-phenyl-1,3-dioxane is correlated in a very linear fashion ($r = 0.98$) to Hammett σ_m parameters (Figure 1-22). Consequently, the conformational energy of a 5-phenyl group is adjustable, or tunable, in a predictable and rather precise way by reference to Hammett constants that account for the effect of substituents on the acidity of benzoic acids.

In a larger sense, the results of this investigation of the conformational behavior of 5-phenyl-1,3-dioxanes reinforces the notion that non-classical CH \cdots X hydrogen bonds are often relevant to an understanding of broader conformational issues involving heterocyclic systems bearing aryl substituents.

1.5 The Anomeric Effect Revisited

Given the results described above, it appears that electrostatic interactions within small molecules play a more significant role than previously thought in establishing conformational preferences. The investigation of the 2,2-diaryl-1,3-dioxane system¹² demonstrated that substituted aryl rings with remote electron-donating substituents preferentially adopt the axial position within such systems while aryl rings with remote electron-withdrawing substituents preferentially adopt the equatorial position. Analysis of the free-energy differences between the anomeric diastereomers established that a unique solvent effect occurs with these systems: the more polar solvent stabilizes the molecule with the lower dipole moment, contrary to the normally observed trend.⁵¹

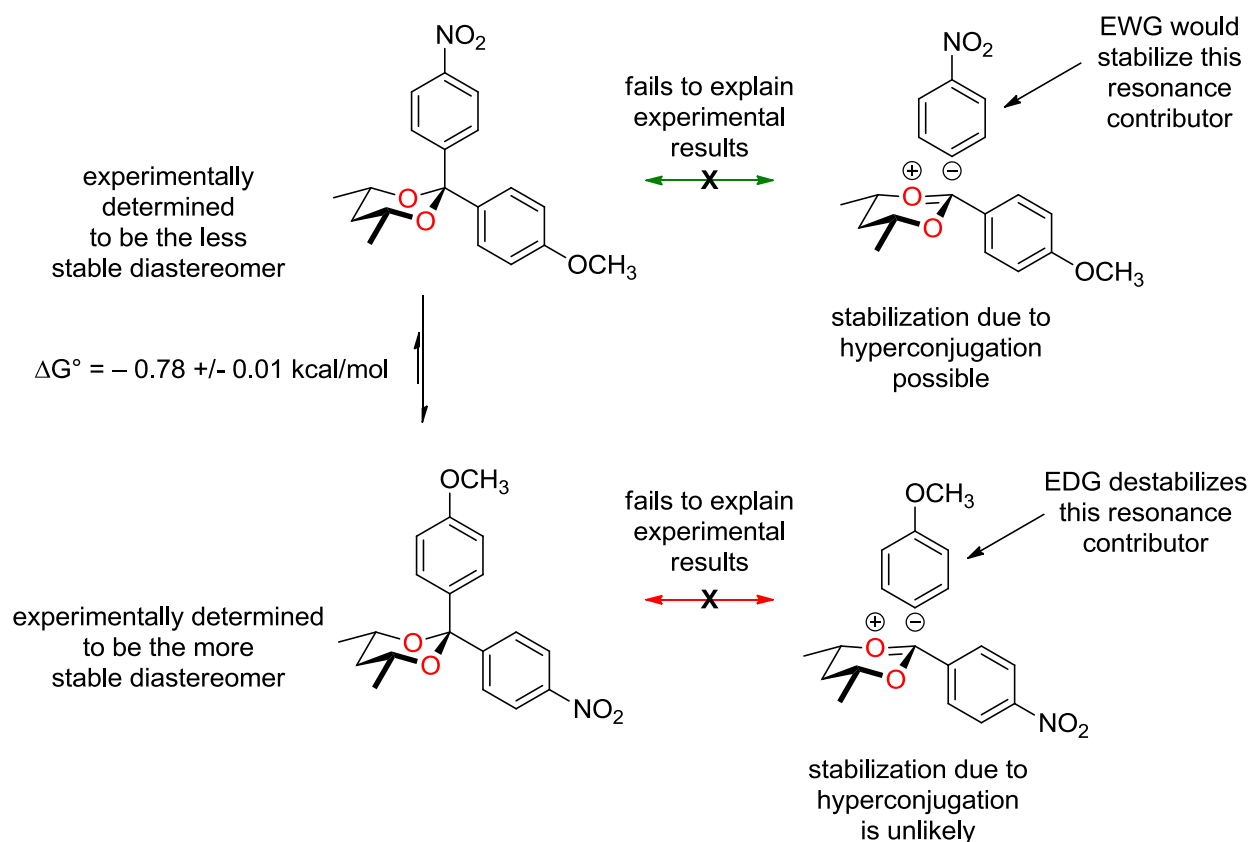


Figure 1-27

The presence of a slight solvent effect and the strong correlation to the Hammett parameters for substituted benzoic acids leads to the conclusion that the origin of the conformational preferences is electrostatic in nature. Clearly, one cannot invoke hyperconjugative interactions to explain the

conformational preferences observed in 2,2-diaryl-1,3-dioxanes, as the order of stabilization from the remote substituent on the axial aryl ring is opposite of that expected from a hyperconjugative effect (Figure 1-27). As illustrated in Figure 1-27, the diastereomer with the aryl ring containing the electron-donating methoxy group positioned axial is more stable by 0.78 ± 0.1 kcal / mol in diethyl ether solvent. Were hyperconjugation the source of this conformational preference, it would result in stabilization of the less stable diastereomer.

The experimental data suggest that an electrostatic interaction exists between the aryl ring and the C(4) and C(6) carbons and/or hydrogens, which are inherently more positive; a result of the induced dipole created from the ring oxygens. The exact stabilizing interaction is challenging to decipher, but is the result of the fact that remote substituents which donate electron density into the aryl ring decrease the following: 1) the overall positive character of the π -system, 2) the positive charge on the hydrogens that are positioned *ortho* to the *ipso* carbon,⁵² and, 3) the positive charge on the carbons that are positioned *ortho* to the to the *ipso* carbon. When the aryl rings with electron-donating substituents are located in the axial position a favorable electrostatic stabilization exists between the transannular C(4) and C(6) carbons and/or hydrogens and the aryl π -system as a whole, and/or the *ortho*-hydrogens, and/or the *ortho*-carbons. (Figure 1-28).

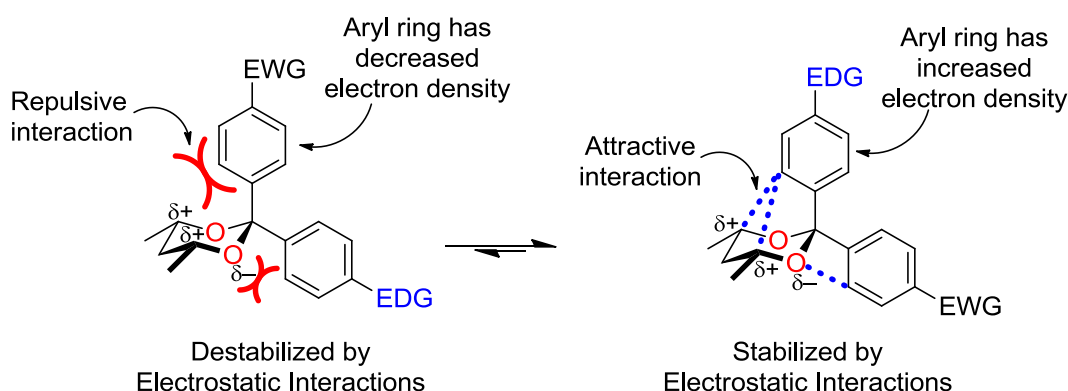


Figure 1-28

The transannular electrostatic interaction discussed above is likely responsible for the conformational differences observed in the 2,2-diaryl-1,3-dioxane system, and further support for this

conclusion is gathered from the results of the investigation of the substituted 5-aryl-1,3-dioxane system. It was determined that in the 5-aryl-1,3-dioxane system a Columbic attraction exists between an *ortho*-hydrogen of the aryl ring and the ring oxygens resulting in the formation of a stabilizing non-classical CH \cdots O hydrogen bond when the aryl ring is in the axial orientation. As detailed above, the strength of this Columbic interaction can be enhanced by increasing the electron-withdrawing nature of the remote substituent on the aryl ring (Figure 1-29).

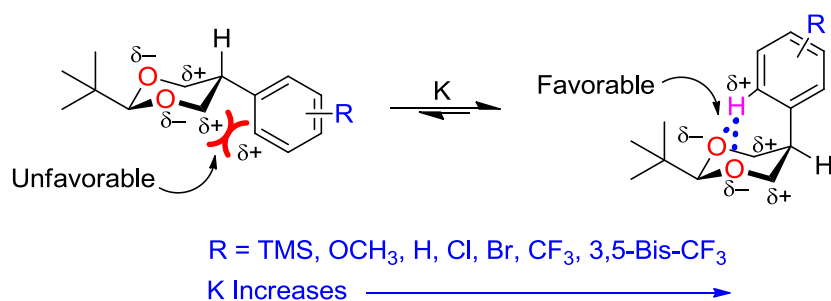


Figure 1-29

From the experimental and computational investigations described above, it is clear that electrostatic interactions play a significant role in determining the conformational equilibria in heterocyclic systems. In order to further probe the effect of such interactions, and to offer further insight into the origin of the “anomeric effect”, a series of anancomeric cyanocyclohexanes and 2-substituted-1,3-dioxanes were prepared as illustrated below (Schemes 1-5, 1-6, and 1-8), and the conformational preferences were experimentally determined.

The cyanocyclohexane systems were conveniently equilibrated using base (potassium *tert*-butoxide) since the α -hydrogen is fairly acidic ($pK_a \sim 25$); the process is illustrated in Figure 1-30. The A-value of the cyano group has been previously determined on a number of occasions⁵³, which allows for a comparison of our experimental approach to those previously reported.⁵⁴ Additionally, the compounds are easily prepared using the methods described in Part I.

Base-Catalyzed Equilibration:

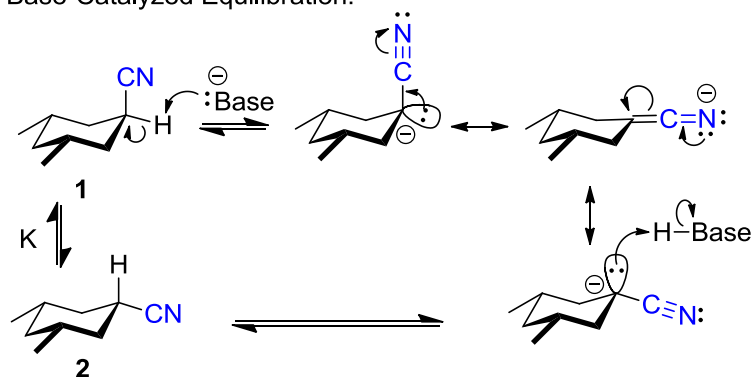


Figure 1-30

It was reasoned that by altering the electron-withdrawing nature of substituents attached to the C(3) and C(5) positions of cyanocyclohexane, analogous to the C(4) and C(6) carbons of 1,3-dioxane, electrostatic interactions could be probed as there are no hyperconjugative interactions present to stabilize the cyano group in cyanocyclohexane (Figure 1-31).

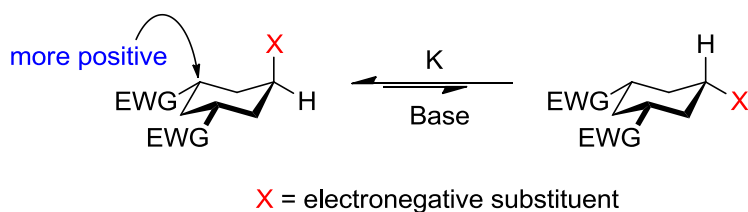
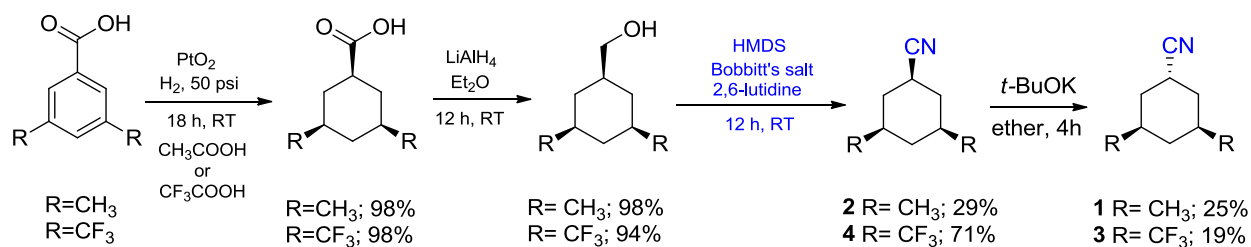


Figure 1-31

To this end, compounds **1** and **2** along with the bis-trifluoromethyl analogs (**3**) and (**4**) were synthesized from the relevant benzoic acids as shown in Scheme 1-5.



Scheme 1-5

Diastereomers **1** and **2** were equilibrated with potassium *tert*-butoxide^{53a-b} at room temperature in three solvents: tetrahydrofuran, diethyl ether, and cyclohexane. The equilibrium was approached independently from both sides starting with pure **1** and then again from pure **2**, and equilibration process

was deemed complete when the area ratios obtained by GC analysis were found to be the same from each side. The results are summarized in Table 1-12. The experimental free energy difference (**1** \rightarrow **2**) of -0.233 ± 0.001 kcal/mol in THF at 23 °C is in agreement with the A-value of 0.25 kcal/mol determined by Allinger from the equilibration of 4-*tert*-butylcyclohexanecarbonitrile with potassium *tert*-butoxide in THF solvent at 66 °C.^{53a} Jensen^{53b} determined the A-value of a cyano group to be between -0.141 ± 0.005 kcal/mol and -0.191 ± 0.010 kcal/mol from the equilibration of 4-*tert*-butylcyclohexanecarbonitrile with potassium *tert*-butoxide in *t*-BuOH solvent at various temperatures. Later, Jensen and Schneider determined A-values of: 0.240 ± 0.003 kcal/mol (CS₂-TMS, 90:10)^{53c} and 0.214 ± 0.02 kcal/mol (CFCl₃-TMS, 95:5)^{53d} by low-temperature NMR analysis of cyclohexanecarbonitrile. As evidenced in the results shown in Table 1-12, there appears to be a slight solvent effect at play, which suggests there is an interruption of an electrostatic interaction by the solvent medium. In the most polar solvent, THF, the molecule with the higher dipole moment (**2**) is stabilized relative to the axial isomer (**1**). In the least polar solvent studied, cyclohexane, the free energy difference between **1** and **2** decreases. The difference in free energy differences ($\Delta\Delta G^\circ$) in going from THF solvent to cyclohexane solvent is ~ 0.12 kcal/mol.

Table 1-12

entry	solvent	K ^a	ΔG° , ^a kcal/mol
1	THF	1.485 ± 0.003	-0.233 ± 0.001
2	Et ₂ O	1.359 ± 0.011	-0.181 ± 0.005
3	<i>c</i> -C ₆ H ₁₂	1.223 ± 0.001	-0.118 ± 0.001

^aDetermined at 23 °C; errors are propagated standard deviations.

Diastereomers **3** and **4** were also equilibrated with potassium *tert*-butoxide at room temperature in the same three solvents for comparison to the free energy difference between **1** and **2**. The equilibrium was approached independently from both sides (from pure **3** and pure **4**) in the same manner as detailed

for compounds **1** and **2** above. The results are shown in Table 1-13. Clearly, the electron-withdrawing nature of the bis-trifluoromethyl holding groups has a substantial effect on the conformational equilibria of the cyano group. In THF solvent, the free energy difference is found to be -0.168 ± 0.002 kcal/mol (**3** \rightarrow **4**), which demonstrates that the cyano group is found to be more axial when compared to dimethyl derivatives **1** and **2** in the same solvent, but the difference is only 0.065 kcal/mol. The more remarkable, and significant findings arise from the equilibration of **3** and **4** in the less polar solvents, diethyl ether and cyclohexane.

Table 1-13

3 $\xrightleftharpoons[t\text{-BuOK}]{K = 4/3}$ **4**

entry	solvent	K^a	$\Delta G^\circ,^a$ kcal/mol
1	THF	1.329 ± 0.004	-0.168 ± 0.002
2	Et ₂ O	0.785 ± 0.003	$+0.259 \pm 0.001$
3	<i>c</i> -C ₆ H ₁₂	0.422 ± 0.001	$+0.480 \pm 0.001$

^aDetermined at 23 °C; errors are propagated standard deviations.

In diethyl ether and cyclohexane, the free energy difference reverses and compound **3** is found to be more stable than compound **4**: in diethyl ether, $\Delta G^\circ = +0.259 \pm 0.001$ kcal/mol (**3** \rightarrow **4**), and in cyclohexane, $\Delta G^\circ = +0.480 \pm 0.001$ kcal/mol (**3** \rightarrow **4**). This result is unprecedented as the only known substituents found to have negative A-values are the acetoxy- and chloromercuri groups as a result of the long C–Hg bond and the polarizable nature of the mercury atom.⁵⁵ This result most certainly is electrostatic in origin.

There is a much greater solvent effect observed in the bis-trifluoromethyl analogues (**3** and **4**), with the same general trend being observed as in compounds **1** and **2**; the diastereomer containing the equatorial cyano group (**4**) is stabilized by the more polar solvent. The difference in free energy differences ($\Delta\Delta G^\circ$) in going from THF solvent to cyclohexane solvent for the bis-trifluoromethyl

derivatives (**3** and **4**) is ~ 0.65 kcal/mol; approximately a six-fold increase than what is observed for the dimethyl derivatives (**1** and **2**).

The behavior of **3** \rightarrow **4** is most certainly due to an intramolecular, electrostatic stabilizing effect. The introduction of the trifluoromethyl holding groups, as opposed to methyl holding groups, is worth ~ 0.6 kcal/mol towards stabilizing an axial cyano group. Simple analysis of the origin of this stabilizing effect is complicated by the fact that the cyano group itself contains both a positive carbon and a negative nitrogen. It is more convenient to sum the charges of both the negative nitrogen and the positive carbon to determine an overall charge of the cyano group, which as a result, is negative. Then by using the midpoint of the C–N bond in relation to the C(3) and C(5) H's, one can quantify the overall attractive CH \cdots CN interaction. Work is currently underway to compute the Hirshfeld charges from computed lowest energy structures in order to elucidate the significance of the introduction of trifluoromethyl groups into cyanocyclohexane systems.

Briefly inspecting the MP2 calculated structures shown in Figure 1-32, it is clear that in compounds **2** and **4**, the interatomic distances between the C(3) and C(5) hydrogens and the axial substituent, the C(1) hydrogen, are virtually the same with a distance of 2.55 Å. However, in compounds **1** and **3**, there are noticeable changes in these interatomic distances. In compound **1**, the C(3) and C(5) hydrogens and the axial C(1) cyano carbon, are calculated to be 2.70 Å apart; whereas, in relation to the cyano nitrogen, the distance is 3.16 Å. In compound **3**, the C(3) and C(5) hydrogens and the axial C(1) cyano carbon, are calculated to be 2.67 Å apart; whereas, in relation to the cyano nitrogen, the distance is 3.10 Å; these distances are closer in **3** than in **1**.

As depicted in Figure 1-32, there is a slight change in the H1–C1–CN1 bond angle between compounds **1** and **3**: compound **1** displays a bond angle of 107.0°, but compound **3** exhibits a larger angle of 107.5°, in which the cyano group in compound **3** leans into the cyclohexane ring by 0.5° as compared to compound **1**. In analyzing the analogous 3,5-substituted computed structures, but with the replacement of the cyano group with a fluorine a similar trend is observed.

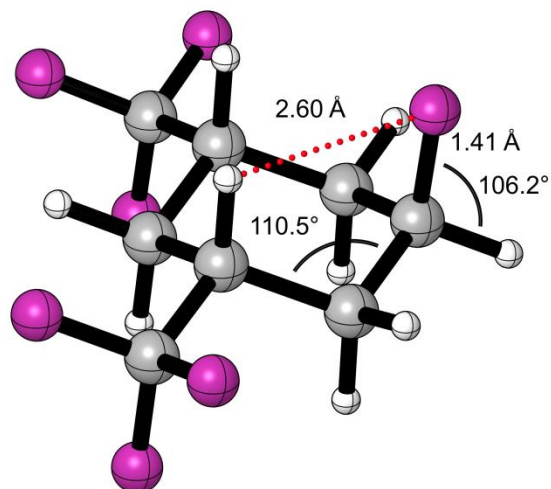
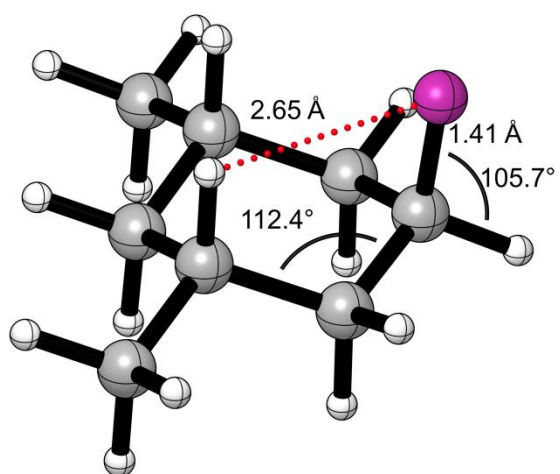
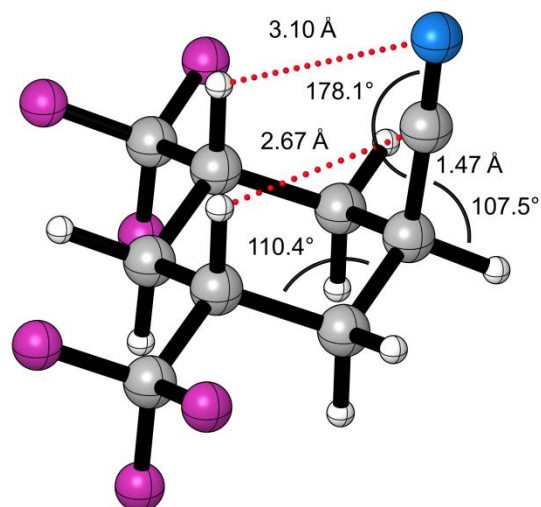
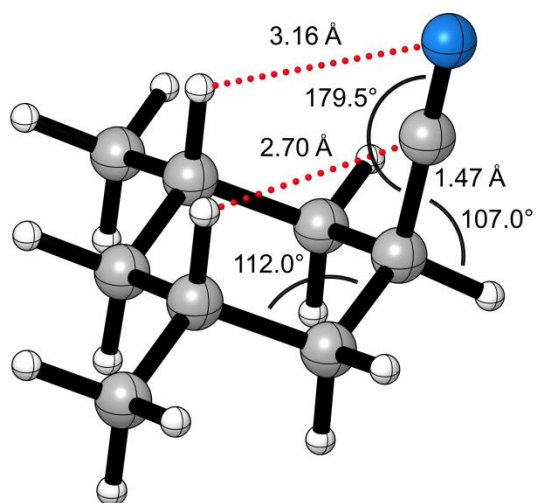
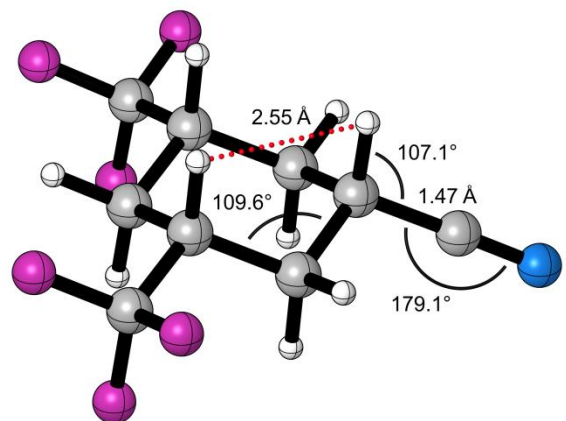
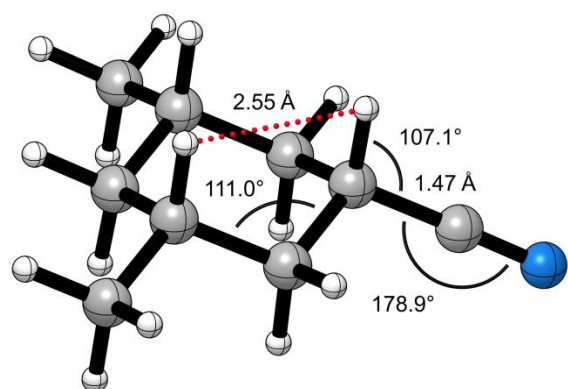


Figure 1-32

In the dimethyl-substituted fluorocyclohexanes shown in Figure 1-32, the interatomic distance between the C3 and C5 hydrogens and the axial fluorine is 2.65 Å, and the compound displays a H1–C1–F1 bond angle of 106.2°. In the bistrifluoromethyl-substituted fluorocyclohexane, the interatomic distance between the C3 and C5 hydrogens and the axial fluorine is 2.60 Å, and the compound displays a H1–C1–F1 bond angle of 105.7°; a 0.5° deviation into the cyclohexane ring.

The computed data and the experimentally determined free energy differences demonstrate that replacement of two methyl holding groups with trifluoromethyl groups alters the A-value of a cyano group from +0.2 to –0.5 kcal/mol. The origin of this result is a stabilizing electrostatic interaction between the positive C(3) and C(5) carbons and/or the attached hydrogens and the electronegative substituent at C(1). This result reinforces the idea that electrostatic interactions play a critical role in determining the conformational preferences of small molecule systems.

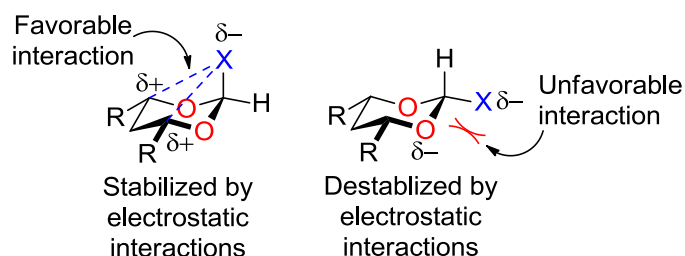
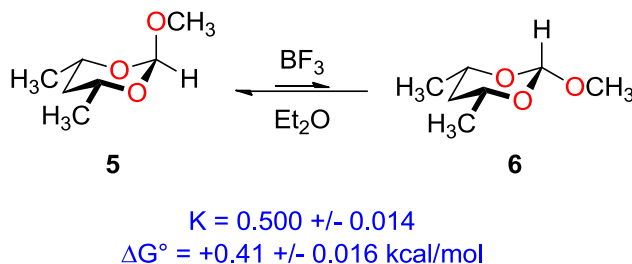


Figure 1-33

Extending the findings to 1,3-dioxane systems (Figure 1-33) is the next logical step. This analysis may allow one to separate the hyperconjugative and electrostatic contributions. Recently, Mo and co-workers noted:

“Applying the BLW method to the anomeric effect, we have profoundly demonstrated that the hyperconjugation can play either positive or negative roles in the conformational preferences of various anomeric and generalized anomeric systems. But even when the hyperconjugation plays a positive role, it contributes less than 50% to the α – β energy gap. Thus, we conclude that the steric effect, or more specifically the electrostatic interaction, dominates the anomeric effect.”^{51b}

If Mo's argument is correct, the introduction of bis-trifluoromethyl holding groups in place of dimethyl holding groups in the C(4) and C(6) positions of 1,3-dioxane would have a marked effect on the anomeric tendencies of substituents at the C(2) position.



Scheme 1-6

A classic model system that displays a pronounced anomeric effect is the 2-methoxy-1,3-dioxane system originally investigated by Eliel and Nader^{15b} (Scheme 1-6). It was determined that in diethyl ether solvent, compound **5**, in which the methoxy group on C(2) is axial, is ~0.4 kcal/mol more stable than compound **6**, in which the methoxy group on C(2) is positioned equatorial. In order to further investigate the electrostatic interactions within this system, it was of interest to determine the free energy differences between **5** and **6** in additional solvents. Compounds **5** and **6** were prepared as a mixture by the method of Eliel and Nader^{15b} and the isolation of pure **5** and pure **6** was achieved by column chromatography as described in the Experimental Section. The free energy difference between **5** and **6** was determined in the usual manner.^{12, 39} The results are summarized in Table 1-14. The free energy difference between **5** and **6** determined in diethyl ether (Table 1-14, entry 3) is, within the combined experimental error, identical to the value determined by Eliel and Nader.^{15b} Additionally, by obtaining the same equilibrium constant (*K*) when employing Amberlyst-15 as the acid catalyst, instead of boron trifluoride diethyl etherate, reinforces the fact that the same equilibrium constant should be obtained independent of the acid catalyst.

As illustrated in Table 1-14 there is a substantial solvent effect observed for the 2-methoxy-1,3-dioxane system as the difference in free energy differences ($\Delta\Delta G^\circ$) in going from acetonitrile solvent to cyclohexane solvent is ~ 0.50 kcal/mol, with the equilibrium reversing in acetonitrile; **6** is slightly favored over **5** (Table 1-14, entry 1). Again, the existence of this large solvent effect is the result of the solvent

medium interrupting the stabilization provided by intramolecular electrostatic interactions. Given the results of our recent study³⁹ on substituted 5-aryl-1,3-dioxane systems, which is described above, the large contrasteric preference for **5** over **6** is clearly the result of a CH \cdots OCH₃ Columbic interaction. If this is truly the case, the introduction of two trifluoromethyl holding groups will “tune” the equilibrium to favor the diastereomer with the axial methoxy group to an even greater extent.

Table 1-14

5 $\xrightleftharpoons[\text{Amberlyst-15 or AlCl}_3]{K = 6 / 5}$ **6**

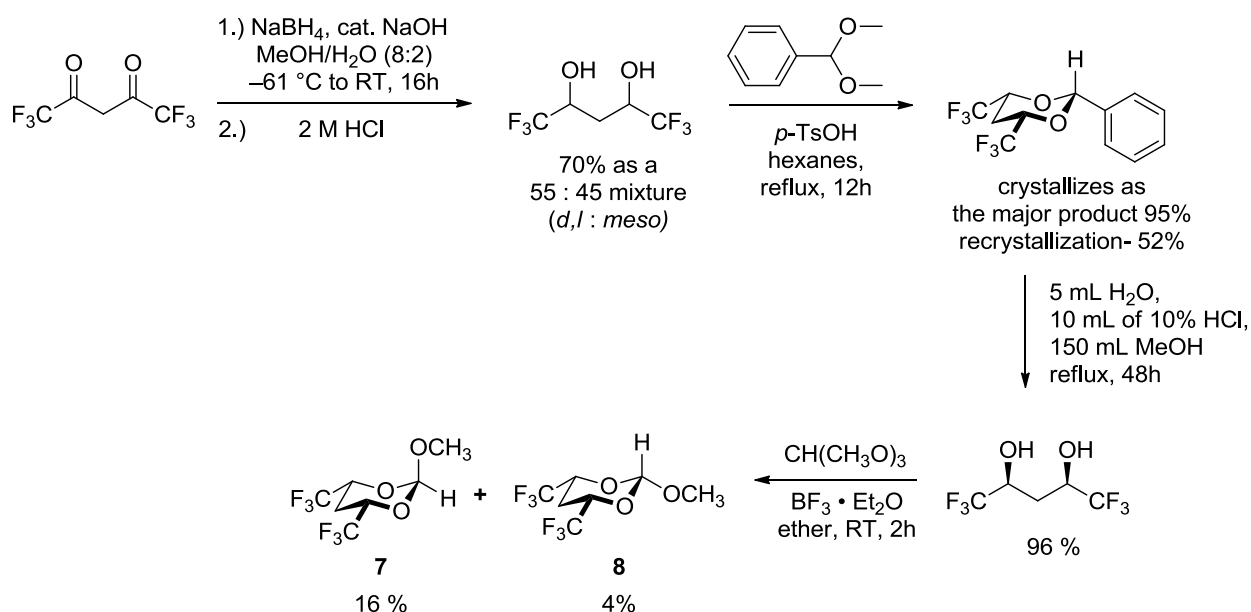
entry	solvent	K ^a	ΔG° , ^a kcal/mol
1	CH ₃ CN	1.075 ± 0.001	−0.042 ± 0.001
2	THF	0.643 ± 0.002	+0.259 ± 0.001
3	Et ₂ O	0.508 ± 0.003	+0.399 ± 0.003
4	<i>c</i> -C ₆ H ₁₂	0.421 ± 0.002	+0.509 ± 0.002
5	C ₅ H ₁₂	0.399 ± 0.001	+0.541 ± 0.001

^aDetermined at 23 °C; errors are propagated standard deviations.

The introduction of the trifluoromethyl holding groups to afford compounds **7** and **8** is accomplished, with difficulty, as depicted in Scheme 1-7. It is worth noting that the electronic differences of 1,1,1,5,5,5-hexafluoro-2,4-pentanediol as compared to 2,4-pentanediol prevents the direct condensation of the fluorinated diol with benzaldehyde, and requires a transacetalization with benzaldehyde dimethylacetal to afford the 2-phenyl-1,3-dioxane analogue. Fortunately, due to the large A-value of 2.4–2.5 kcal/mol for the trifluoromethyl group, which is even larger in 1,3-dioxane, *r*-2-phenyl-*cis*-4,*cis*-6-bis(trifluoromethyl)-1,3-dioxane is isolated as the major product of the condensation. The hydrolysis of the phenyl dioxane to afford *meso*-1,1,1,5,5,5-hexafluoro-2,4-pentanediol is slow as the intermediate is destabilized by the trifluoromethyl groups. The final step in preparing compounds **7** and **8** was also difficult to accomplish as attempts to perform the condensation with typically employed acid catalysts such as *p*-TsOH, camphorsulfonic acid, and pyridinium *p*-toluenesulfonate either resulted in

decomposition of the diol through hydrolysis or failed to initiate the condensation. However, employing $\text{BF}_3 \cdot \text{Et}_2\text{O}$ as a lewis acid allowed for a moderate yield of compounds **7** and **8**, but only if the reaction was conducted at room temperature, as higher temperatures promoted dehydration of the diol.⁵⁶ Careful column chromatography on neutral alumina as described in the Experimental Section allowed for the isolation of pure **7** and pure **8**.

Given the complications encountered in the final step of the synthesis of compounds **7** and **8**, the acid catalyst chosen for the equilibrations was anhydrous solid aluminum trichloride, as it was soluble in the solvents of interest, and allowed for the clean equilibration without any deleterious side-reactions or decomposition. Other than employing a different acid catalyst, the equilibrations were conducted in the same manner as for compounds **5** and **6**. The results are illustrated in Table 1-15.



Scheme 1-7

From the results listed in Table 1-15, it is clear that the introduction of trifluoromethyl holding groups to the C(4) and C(6) positions of 2-methoxy-1,3-dioxane dramatically increases the conformational free energy difference. The free energy difference between **5** and **6** in cyclohexane solvent (Table 1-14, entry 4) is 0.509 ± 0.002 kcal/mol favoring **5**, in comparison, the free energy difference between **7** and **8** in cyclohexane solvent (Table 1-15, entry 3) is 1.575 ± 0.004 kcal/mol

favoring **7**. The difference in free energy differences ($\Delta\Delta G^\circ$) between the diastereomeric pairs (**5** and **6**; **7** and **8**) in cyclohexane solvent is ~ 1.06 kcal/ mol.

Table 1-15

entry	solvent	K^a	$\Delta G^\circ,^a$ kcal/mol
1	THF	0.193 ± 0.001	$+0.986 \pm 0.002$
2	Et ₂ O	0.148 ± 0.002	$+1.123 \pm 0.006$
3	<i>c</i> -C ₆ H ₁₂	0.069 ± 0.001	$+1.575 \pm 0.004$

^aDetermined at 23 °C; errors are propagated standard deviations.

The large stabilization (~ 1.6 kcal/mol) of the axial diastereomer (**7**) over **8** undoubtedly stems from the strengthening of the CH \cdots OCH₃ non-classical hydrogen bond between the C(4) and C(6) H's of the dioxane ring and the oxygen of the methoxy group attached to C(2). The introduction of the trifluoromethyl holding groups to the C(4) and C(6) positions of the dioxane ring is computed to result in a shortening of the C(4)–O(3) and C(6)–O(1) bond lengths as shown in Figure 1-34. As one might expect, the trifluoromethyl groups also withdraw electron density from the ring oxygens, which explains the shortening of these bond lengths. Most importantly, the trifluoromethyl groups positioned at C(4) and C(6) of the dioxane ring should decrease any stabilizing hyperconjugative effects, as the ring oxygens are less likely to donate electron density into the antibonding orbital of C(2); in light of this, there is a more pronounced “anomeric effect” in the trifluoromethyl compounds (**7** and **8**) as the methoxy group adopts the axial position to a greater extent than in the dimethyl analogues (**5** and **6**).

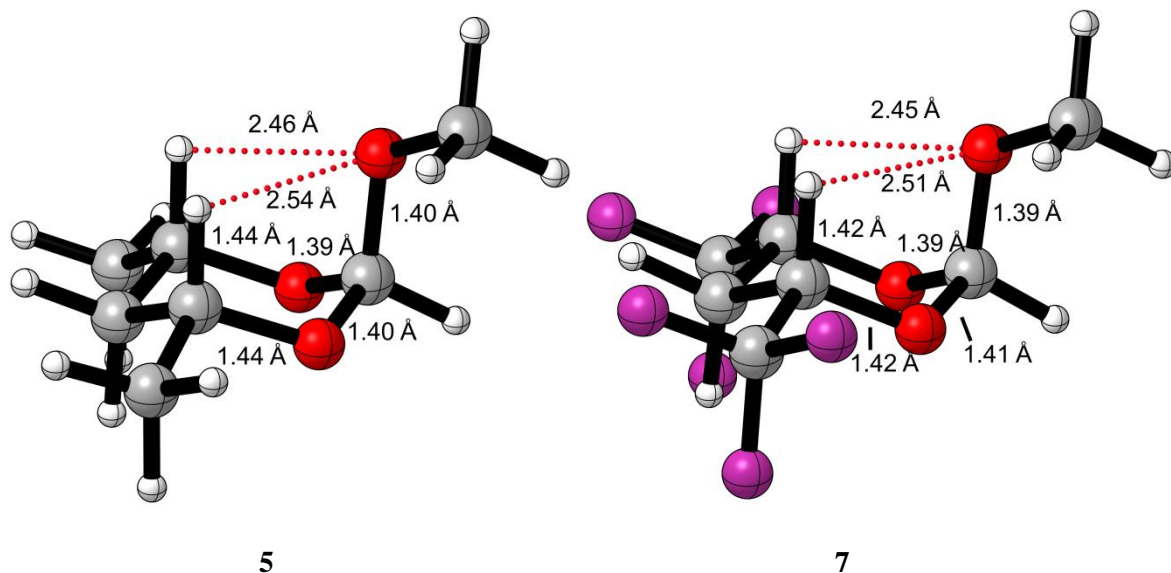
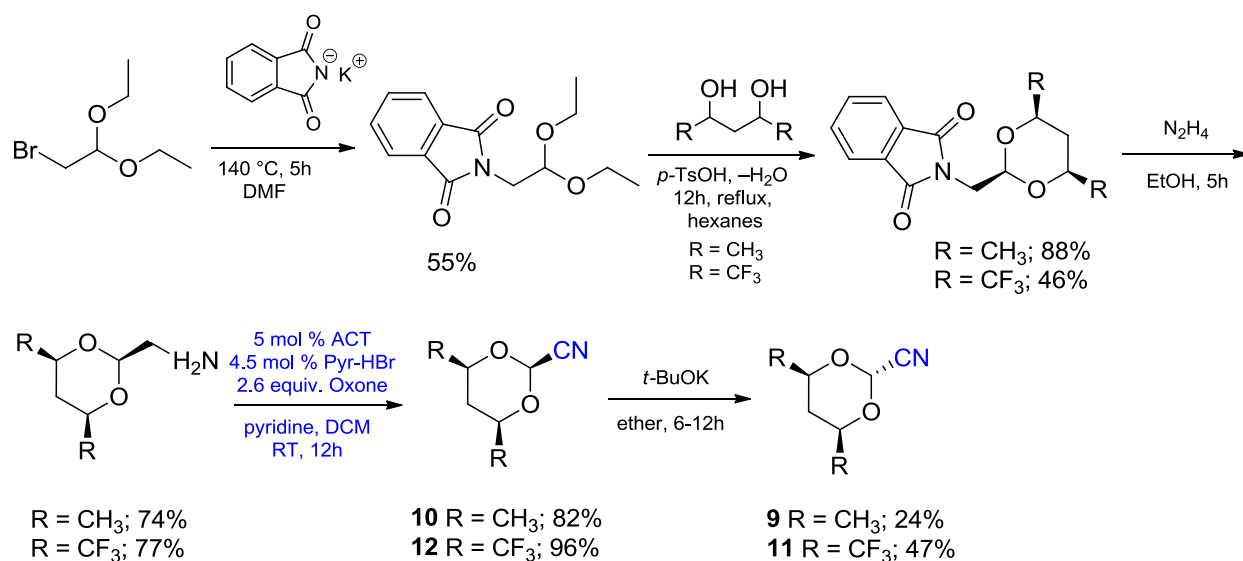


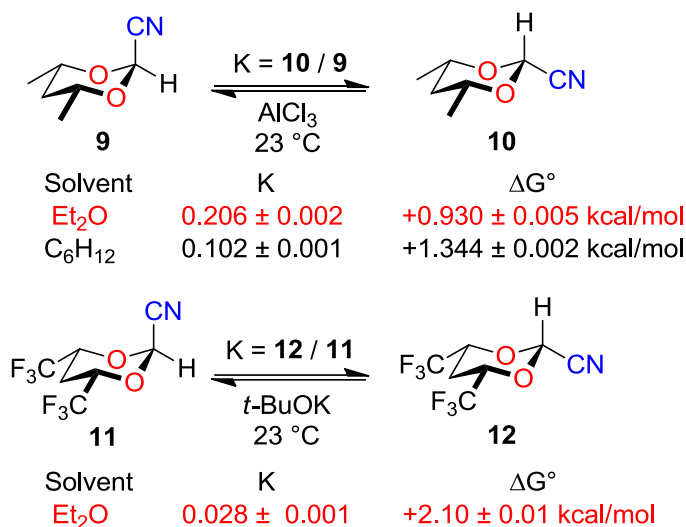
Figure 1-34

For a more direct comparison with the cyanocyclohexanes investigated earlier, a series of 2-cyano-1,3-dioxanes have been prepared. The cyano group has not been previously studied in 1,3-dioxane systems at the C(2) anomeric position, as it is synthetically challenging to introduce the nitrile. Typical methods to introduce the nitrile functionality such as the dehydration of an amide require harsh conditions that would result in the hydrolysis of the dioxane or ring-opened products. As described above, the oxidation of primary amines to nitriles with oxoammonium salt reagents is accomplished in high yield under mild enough conditions to tolerate acid-sensitive functional groups such as dioxanes. Using the published catalytic method described above⁵⁷, the synthesis of 2-cyano-1,3-dioxanes is possible and is accomplished as shown in Scheme 1-8; the oxidation proceeds in 82% yield to furnish compound **10** and in a 92% yield to afford compound **12**. Compounds **9** and **11** are easily accessed from their respective diastereomers through the base-catalyzed equilibration process and then purified by preparative TLC.



Scheme 1-8

The equilibration of 2-cyano-1,3-dioxanes differs from other dioxanes, in that, the attempted acid-catalyzed equilibration with *p*-TsOH fails to proceed; the result of the inability to form the cationic intermediate required for the process, as well as, decomposition into unidentified products. However, compounds **9** and **10** can be equilibrated with aluminum trichloride and the process takes 1–2 weeks to reach equilibrium. The equilibrium constant was determined in diethyl ether and cyclohexane solvent in the same manner described above for compounds **7** and **8**. The results are shown in Scheme 1-9. Compounds **11** and **12** do not easily undergo acid-catalyzed equilibration. For example, a sample of **12** did not form any appreciable amount of **11** (less than 2%) upon standing in anhydrous diethyl ether solvent with a 10-fold molar excess of aluminum trichloride for a period of two months. Equilibration of compounds **11** and **12** is reasonably accomplished under dilute basic conditions in anhydrous diethyl ether solvent requiring 36–48 h to reach equilibrium. Compounds **11** and **12** were only equilibrated in diethyl ether as in cyclohexane solvent neither compound was sufficiently soluble to allow for the accurate determination of an equilibrium constant. Equilibrium was approached independently from both sides starting with pure **11** and pure **12** as described above. The results are shown in Scheme 1-9.



Scheme 1-9

As with the 2-methoxy-1,3-dioxane analogues, the replacement of the C(4) and C(6) methyl holding groups with trifluoromethyl holding groups in 2-cyano-1,3-dioxane substantially increases the conformational preference of the cyano group to occupy the axial position. These findings, while remarkable, are not surprising given the results of the investigation of the cyanocyclohexane systems described above. As noted, the C(4) and C(6) carbons of 1,3-dioxane are analogous to the C(3) and C(5) carbons found in the cyanocyclohexane systems, with the exception that they are inherently closer to the substituent of interest due to the shorter C–O bond lengths within the ring (Figure 1-35). Thus, one would predict that if the proposed transannular electrostatic interaction does exist, it would be strengthened due to the increased proximity of the attractive Columbic charges; this is what is experimentally observed. Furthermore, the MP2 calculated structures do reveal small changes in bond lengths in going from **9** to **11**.

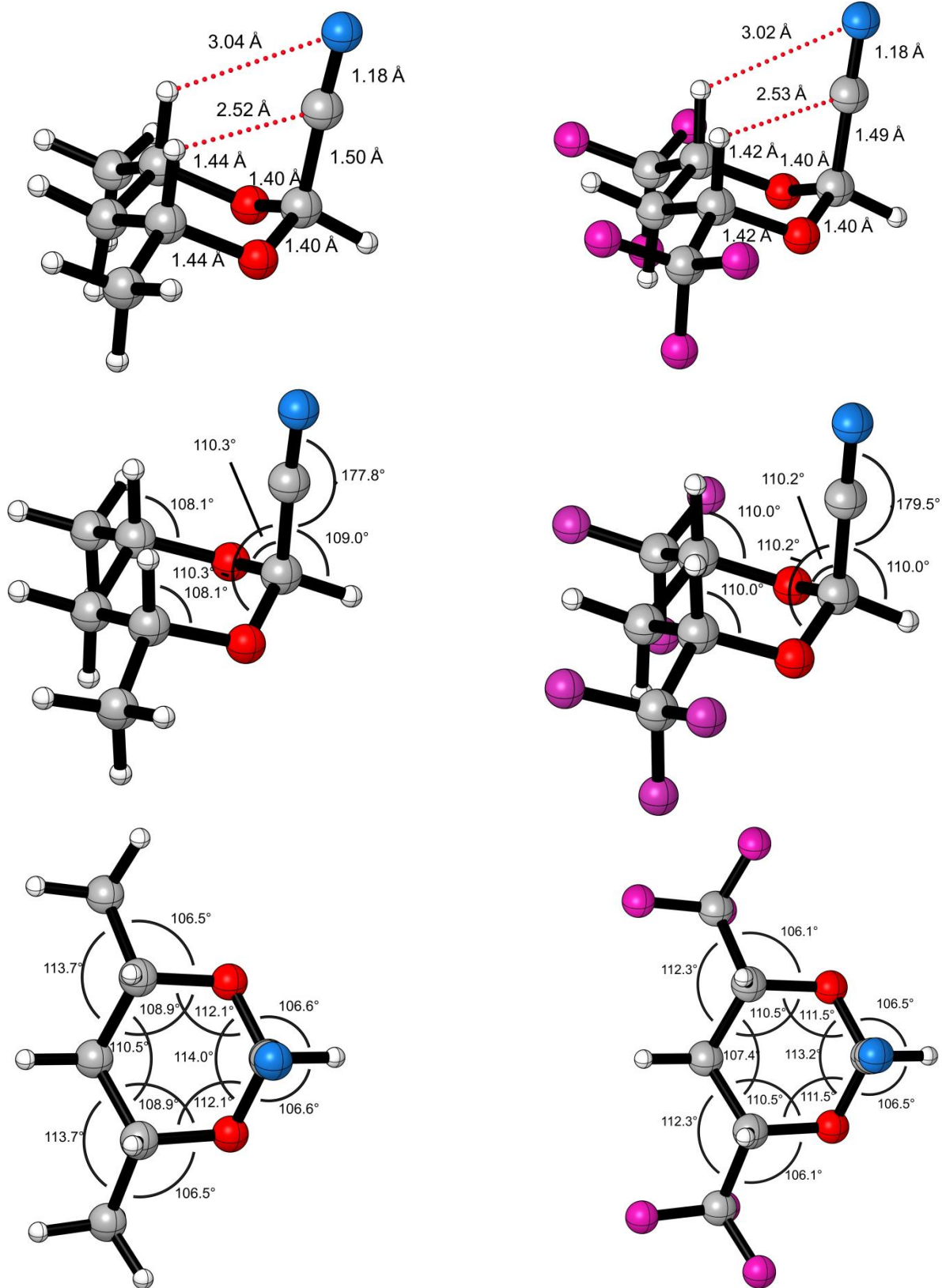


Figure 1-35

The significance of the results described in this section has yet to be fully determined, but it is clear that by enhancing the positive character of the C(3) and C(5) positions in cyanocyclohexyl systems and the C(4) and C(6) carbons and/or the attached hydrogens in analogous 2-substituted-1,3-dioxane systems, the conformational preference of substituents, at C(1) in the cyclohexyl system, and C(2) in the dioxanes, can be biased to adopt the axial orientation. Additionally, these data suggest that electrostatic interactions are a significant determinant of the conformational equilibria observed in small molecules.

Chapter I References

- ¹ Edward, J. T. *Chem Ind.* **1955**, 1102–1104.
- ² (a) Lemieux, R.L.; Chü, P. *Abstracts of Papers*; 133rd National Meeting of the American Chemical Society, San Francisco, CA; American Chemical Society: Washington, DC, **1958**; p 31N (b) Chü, N. J. Ph. D. Thesis, University of Ottawa, **1959**.
- ³ For reviews of the “Anomeric Effect” see: (a) Lemieux, R. U. *Pure Appl. Chem.* **1971**, 25, 527. (b) Eliel, E. L. *Angew. Chem. Int. Ed.* **1972**, 11, 739. (c) *Anomeric Effect: Origin and Consequences*; Szarek, W. A.; Horton, D., Eds.; ACS Symposium Series 87; American Chemical Society: Washington, DC, 1979. (d) Deslongchamps, P. *Stereoelectronic Effects in Organic Chemistry*; Pergamon: New York, 1983. (e) Kirby, A. J. *The Anomeric Effect and Related Stereoelectronic Effects at Oxygen*; Springer-Verlag: New York, 1983. (f) Tvaroska, I.; Bleha, T. *Adv. Carbohydr. Chem. Biochem.* 1989, 47, 45. (g) Box, V. G. S. *Heterocycles* **1990**, 31, 1157. (h) Juaristi, E.; Cuevas, G. *Tetrahedron* **1992**, 48, 5019. (i) Juaristi, E.; Cuevas, G. *The Anomeric Effect*; CRC Press: Boca Raton, 1995. For other related conrotational effects see: (j) Wolfe, S. *Acc. Chem. Res.* **1972**, 5, 102–111. (k) Juaristi, E. *J. Chem. Educ.* **1979**, 56, 438. (l) Wiberg, K. B.; Murcko, M. A.; Laidig, K. E.; MacDougall, P. J. *J. Phys. Chem.* **1990**, 94, 6956–6959.
- ⁴ Bailey, W.F.; Eliel, E. L. *J. Am. Chem. Soc.*, **1974**, 96, 1798–1806.
- ⁵ Lemieux, R.U.; Morgan, A.R. *Can. J. Chem.*, **1965**, 43, 2205.
- ⁶ Coxon, B. *Tetrahedron* **1966**, 22, 2281.
- ⁷ Anderson, C.B.; Sepp, D.T. *J. Org. Chem.*, **1967**, 32, 607–611.
- ⁸ Kirby, A.J.; Briggs, A.J.; Glenn R.; Jones, P.G.; Ramaswamy, P. *J. Am. Chem. Soc.* **1984**, 106, 6200–6206.
- ⁹ (a) Altona, C.; Romers, C.; Havinga, E. *Tetrahedron Lett.* **1959**, 8, 16. (b) Romers, C.; Altona, C.; Buys, H. R.; Havinga, E. In *Topics in Stereochemistry*, Vol. 4; Allinger, N. L.; Eliel, E. L., Eds.; Wiley-Interscience: New York, 1969, pp 73–77.
- ¹⁰ Fuchs, B.; Ellencweig, A.; Tartakovsky, E.; Aped, P. *Angew. Chem. Int. Ed.* **1986**, 25, 287–289.
- ¹¹ Mo, Y.; *Nat. Chem.* **2010**, 2, 666–671.
- ¹² Bailey, W. F.; Lambert, K. M.; Wiberg, K. B.; Mercado, B. Q. *J. Org. Chem.* **2015**, 80, 4108–4115.
- ¹³ (a) Eliel, E. L.; Bailey, W. F.; Wiberg, K. B.; Connon, H.; Nader, F. W. *Justus Liebigs Ann. Chem.* **1976**, 2240. (b) Bailey, W. F.; Connon, H.; Eliel, E. L.; Wiberg, K. B. *J. Am. Chem. Soc.* **1978**, 100, 2202. (c) Wiberg, K. B.; Castejon, H.; Bailey, W. F.; Ochterski, J. *J. Org. Chem.* **2000**, 65, 1181.
- ¹⁴ Uehara, F.; Sato, M.; Kaneko, C.; Kurihara, H. *J. Org. Chem.* **1999**, 64, 1436.
- ¹⁵ (a) E. L. Eliel, E. L.; Knoeber, M. C. *J. Am. Chem. Soc.* **1968**, 90, 3444. (b) Nader, F. W.; Eliel, E. L. *J. Am. Chem. Soc.* **1970**, 92, 3050. (c) Eliel, E. L. *Acc. Chem. Res.* **1970**, 3, 1.
- ¹⁶ Bonner, L.; Frecas, S.; Nichols, D. E. *Synth. Commun.* **2004**, 34, 2767.
- ¹⁷ Pritchard, J. G.; Vollmer, R. L. *J. Org. Chem.* **1963**, 28, 1545.
- ¹⁸ All thermal ellipsoids are shown at a 50% probability level, and hydrogen atoms are shown as arbitrary spheres.
- ¹⁹ Gaussian 09 Revision D.01, Frisch, M. J.; Trucks, G. W.; Schlegel, H. B.; Scuseria, G. E.; Robb, M. A.; Cheeseman, J. R.; Scalmani, G.; Barone, V.; Mennucci, B.; Petersson, G. A.; Nakatsuji, H.; Caricato, M.; Hratchian, H. P.; Li, X.; Izmaylov, A. F.; Bloino, J.; Zheng, G.; Sonnenberg, J. L.; Hada, M.; Ehara, M.; Toyota, K.; Fukuda, R.; Hasegawa, J.; Ishida, M.; Nakajima, T.; Honda, Y.; Kitao, O.; Nakai, H.; Vreven, T.; Montgomery, Jr., J. A.; Peralta, J. E.; Ogliaro, F.; Bearpark, M.; Heyd, J. J.; Brothers, E.; Kudin, K. N.; Staroverov, V. N.; Kobayashi, R.; Normand, J.; Raghavachari, K.; Rendell, A.; Burant, J. C.; Iyengar, S. S.; Tomasi, J.; Cossi, M.; Rega, N.; Millam, J. M.; Klene, M.; Knox, J. E.; Cross, J. B.; Bakken, V.; Adamo, C.; Jaramillo, J.; Gomperts, R.; Stratmann, R. E.; Yazyev, O.; Austin, A. J.; Cammi, R.; Pomelli, C.; Ochterski, J. W.; Martin, M. L.; Morokuma, K.; Zakrzewski, V. G.; Voth, G. A.; Salvador, P.; Dannenberg, J. J.; Dapprich, S.; Daniels, A. D.; Farkas, O.; Foresman, J. B.; Ortiz, J. V.; Cioslowski, J.; Fox, D. J. Gaussian, Inc., Wallingford, CT **2009**.
- ²⁰ The thermal corrections for ΔG are more sensitive to the low calculated frequencies than is ΔH . It was found necessary to use very tight convergence criteria and a fine grid in order to have agreement between ΔH and ΔG .
- ²¹ (a) Hammett, L. P. *Chem. Rev.* **1935**, 17, 125. (b) Jaffé, H. H. *Chem. Rev.* **1953**, 53, 191.
- ²² Smith, M. B. *March's Advanced Organic Chemistry*; Wiley: Hoboken, 2007, p. 404.
- ²³ The bond to an axial substituent in a six-membered ring is generally longer than that to an equatorial group. For example, the axial C – C bond length in 1,1-dimethylcyclohexane is 1.5411 Å whereas the equatorial length is 1.5374 Å.
- ²⁴ Hirshfeld, F. L. *Theor. Chim. Acta* **1977**, 44, 129.

- ²⁵ Marenich, A. V.; Jerome, S. V.; Cramer, C. J.; Truhlar, D. J. *J. Chem. Theory Comput.* **2012**, *8*, 527.
- ²⁶ (a) Kirkwood, J. G.; Westheimer, F. H. *J. Chem. Phys.* **1938**, *6*, 506. (b) Westheimer, F. H.; Kirkwood, J. G. *J. Chem. Phys.* **1938**, *6*, 513. (c) Sarmousakis, J. N. *J. Chem. Phys.* **1944**, *12*, 277.
- ²⁷ Wiberg, K. B.; Lambert, K. M.; Bailey, W. F. *Tetrahedron Lett.* **2015**, *56*, 3438–3440.
- ²⁸ Allinger, N. L.; Tribble, M.; *Tetrahedron Lett.* **1971**, *55*, 3259–3262.
- ²⁹ Keller, H.; Langer, E.; Lehner, H. *Monatsh. für Chem.* **1976**, *107*, 949–963.
- ³⁰ (a) Hirshfeld, F. L. *Theor. Chim. Acta* **1977**, *44*, 129–138. (b) Parr, R. G.; Ayers, P. N.; Nalewajski, R. F. *J. Phys. Chem. A* **2005**, *109*, 3957–3959.
- ³¹ Experimental studies by Signorell, R.; Marquardt, R.; Quack, M.; and Suhm, M. A. *Mol. Phys.* **1996**, *89*, 297–313 have shown that the charge separation in the C-H bonds of methane is negligible. Vinyl and phenyl hydrogens have a small positive charge as a result of the greater s character in the C-H bonds, and the charge is further increased in acetylene.
- ³² Nguyen, H. M. T.; Diep, P. N.; Zeegers-Huyskens, T. *J. Molec. Struct.* **2009**, *897*, 48–54.
- ³³ Wiberg, K. B. *J. Chem. Ed.* **1996**, *73*, 1089–1095.
- ³⁴ Wiberg, K. B.; Lambert, K. L.; Bailey, W. F. *J. Org. Chem.* **2015**, *80*, 7884.
- ³⁵ The Coulombic energy, $E = q_1 q_2 / r_{12}$, is conveniently calculated in atomic units (Hartrees), using the charge in e, and r in Bohr (1 Bohr = 0.529 Å). We use the Hirshfeld charges, and the conversion factor: 1 H = 627.15 kcal/mol.
- ³⁶ Eliel, E. L.; Enanoza, R. M. *J. Am. Chem. Soc.* **1972**, *94*, 8072.
- ³⁷ Westheimer has pointed out that the Coulombic interaction should be moderated by the fields associated with the other atoms in the molecule; see Ref. 26.
- ³⁸ See for example: (a) Takahashi, O.; Katsuyoshi, K.; Kohno, Y.; Ohtaki, R.; Ueda, K.; Suezawa, H.; Umezawa, Y.; Nishio, M. *Carbohydrate Res.* **2007**, *342*, 1202. (b) Ref. 32 (c) Desiraju, G. B.; Steiner, T. *The Weak Hydrogen Bond in Structural Chemistry and Biology*; Oxford Univ. Press: Oxford, 1999. (d) Nishio, M. *Weak Hydrogen Bonds In Encyclopedia of Supramolecular Chemistry*; Atwood, J. L.; Steed, J. W., Eds.; Marcel Dekker: New York 2004, pp-1576–1585.
- ³⁹ Bailey, W. F.; Lambert, K. M.; Stempel, Z. D.; Wiberg, K. B.; Mercado, B. Q. *J. Org. Chem.* **2016**, *81*, 12116–12127.
- ⁴⁰ For Reviews see Refs. 3b and 15c along with: Eliel, E. L. *Pure Appl. Chem.* **1971**, *25*, 509.
- ⁴¹ Eliel, E. L.; Giza, C. A. *J. Org. Chem.* **1968**, *33*, 3754–3758.
- ⁴² Eliel, E. L.; Wilen, S. H. *Stereochemistry of Organic Compounds*; Wiley: New York, 1994; pp 697–698.
- ⁴³ Ref. 15a, p. 3452.
- ⁴⁴ For a review of non-classical hydrogen bonds, see: Takahashi, O.; Kohno, Y.; Nishio, M. *Chem. Rev.* **2010**, *110*, 6049.
- ⁴⁵ Crystal structure of *cis*-2-*t*-butyl-5-*p*-chlorophenyl-1,3-dioxane (**3**). All thermal ellipsoids are shown at a 50% probability level, and hydrogen atoms are shown as arbitrary spheres. The top view is from the side; the lower view, from above, shows the CH...O interaction.
- ⁴⁶ Hansch, C.; Leo, A.; Taft, R. W. *Chem. Rev.* **1991**, *91*, 165.
- ⁴⁷ Hammett plot of experimental ΔG° values (Table 1-9) determined in cyclohexane solution vs σ_m values. The σ for the 3,5-bis-CF₃ case was calculated from the pK_a of 3,5-bis-CF₃ benzoic acid.
- ⁴⁸ Cioffi, E. A.; Bailey, W. F. *Tetrahedron Lett.* **1998**, *39*, 2679.
- ⁴⁹ Crystal structure of *cis*-2-*t*-butyl-5-(2-pyridyl)-1,3-dioxane (**15**). All thermal ellipsoids are shown at a 50% probability level, and hydrogen atoms are shown as arbitrary spheres. The top view is from the side; the lower view is from above.
- ⁵⁰ Hydrogen bonds with donor-acceptor distances of 2.2–2.5 Å are categorized as “strong, mostly covalent”, those between 2.5–3.2 Å as “moderate, mostly electrostatic”, and between 3.2–4.0 Å as “weak, electrostatic”. See: Jeffery, G. A. “An Introduction to Hydrogen Bonding,” Oxford University Press, 1997, p. 12.
- ⁵¹ See Ref. 41 and the following: a) Booth, H.; Dixon, M. J.; Readshaw, S. A. *Tetrahedron* **1992**, *48*, 6151–6160. b) Wang, C.; Ying, F.; Wu, W.; Mo, Y. *J. Org. Chem.* **2014**, *79*, 1571–1581.
- ⁵² The *ipso* carbon refers to the quaternary carbon that attaches the aryl ring to the anomeric carbon of the 1,3-dioxane.
- ⁵³ Jensen, F. R.; Bushweller, C. H. *Adv. Alicycl. Chem.* **1971**, *3*, 139.
- ⁵⁴ a) Allinger, N. L.; Szkrybalo, W. **1962**, *27*, 4601–4603. b) Rickborn, B.; Jensen, F. R. **1962**, *27*, 4606–4608. c) Jensen, F. R.; Bushweller, C. H.; Beck, B. H. **1969**, *91*, 344–351. d) Schneider, H.-J.; Hoppen, V. *J. Org. Chem.* **1978**, *43*, 3866–3873.

⁵⁵ a) Anet, F. A. L.; Krane, J. *Tetrahedron Lett.* **1974**, 37, 3255–3258 b) Eliel, E. L.; Wilen, S. H. *Stereochemistry of Organic Compounds*; Wiley: New York, 1994; pp 690–700.

⁵⁶ Aluminum trichloride was later found to be just as efficient of a lewis acid as $\text{BF}_3 \cdot \text{Et}_2\text{O}$.

⁵⁷ Lambert, K. M.; Bobbitt, J. M.; Eldirany, S. A.; Kissane, L. E.; Sheridan, R. K.; Stempel, Z. D.; Sternberg, F. H.; Bailey, W. F. *Chem. Eur. J.* **2016**, 22, 5156–5159.

CHAPTER II. EXPERIMENTAL SECTION FOR PART II.

2.1 The Effect of Remote Aryl Substituents on the Conformational Equilibria of 2,2-Diaryl-1,3-dioxanes¹

General Procedures

All commercially available reagents and solvents were of reagent grade and were used without further purification unless otherwise stated. Anhydrous solvents used for the equilibrium studies were dried as follows: dry diethyl ether and THF were freshly distilled from dark-purple solutions of sodium and benzophenone; cyclohexane was dried over anhydrous magnesium sulfate, filtered, and freshly distilled from a dark purple solution of sodium / benzophenone / tetraglyme; acetonitrile was distilled from calcium hydride. The method of Pritchard and Vollmer was followed for the preparation of 2,4-pentanediol as a mixture consisting of ~60% *meso* and ~40% racemic isomers.²

NMR spectra were recorded in CDCl₃ unless otherwise noted on a 400 MHz spectrometer and chemical shifts are reported in ppm. Proton and carbon spectra are reported relative to TMS at $\delta = 0.00$; fluorine spectra are reported relative to CCl₃F at $\delta = 0.00$. Column chromatography was carried out on silica gel (40-63 μm particle size); one column volume of a solution of 0.5 mL of Et₃N in 250 mL of hexanes was run through the column before chromatography of the 2,2-diaryl-*cis*-4,6-dimethyl-1,3-dioxanes to prevent epimerization. Numbered compounds refer to those located in Chart 1-1 above.

Synthesis of 2,2-Diaryl-1,3-dioxanes

***r*-2-*p*-Nitrophenyl-*trans*-4,*trans*-6-dimethyl-2-phenyl-1,3-dioxane (1) and *r*-2-*p*-Nitrophenyl-*cis*-4,*cis*-6-dimethyl-2-phenyl-1,3-dioxane (2).** A mixture of 9.94 g (95.6 mmol) of 2,4-pentanediol, consisting of ~60% *meso* and ~40% racemic isomers, 10.00 g (44.0 mmol) of *p*-nitrobenzophenone, and 300 mg of Amberlyst-15TM resin in 50 mL of cyclohexane was heated at reflux under a Dean-Stark trap for 5 d, at which point the theoretical amount of water had collected in the trap. The reaction mixture was allowed to cool to room temperature and was then filtered to remove the resin, 0.5 g of anhydrous Na₂CO₃ was added to the filtrate, and the mixture was stirred for 1 h to neutralize any residual acid. The mixture was

then poured into a separatory funnel and washed four times with twice the volume of basic water (pH \approx 10) to remove excess diol. The organic layer was dried (Na₂SO₄) and concentrated by rotary evaporation to yield 12.57 g (91 %) of product as a mixture of three diastereomers. A 1.50 g portion of the product mixture was purified by flash chromatography on 60 g of silica gel using a 0 \rightarrow 20% Et₂O / hexanes gradient. Three fractions were collected from the sample: 226 mg (15%) of **1** as white crystals, 582 mg (39%) of **2** as white crystals, and 285 mg (19%) of the unwanted isomer, *r*-2-*p*-nitrophenyl-*cis*-4,*trans*-6-dimethyl-2-phenyl-1,3-dioxane, as white crystals. The epimers, **1** and **2**, were distinguished using two-dimensional ¹H NOESY techniques. Each of the solid isomers were recrystallized, as described below, to give analytical samples used in the equilibration and crystallographic studies.

***r*-2-*p*-Nitrophenyl-*trans*-4,*trans*-6-dimethyl-2-phenyl-1,3-dioxane (1).** R_f = 0.23 (5% Et₂O / hexanes); mp 166 – 167 °C (30% Et₂O / hexanes); ¹H NMR (400 MHz, CDCl₃) δ 1.35 (d, *J* = 6.16 Hz, 6H), 1.44 – 1.54 (m, 2H), 3.88 – 3.96 (m, 2H), 7.21 (t, *J* = 7.24, 1H), 7.28 (t, *J* = 7.48, 2H), 7.54 (d, *J* = 7.60 Hz, 2H), 7.69, (d, *J* = 8.72 Hz, 2H), 8.22 (d, *J* = 8.72 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 21.9, 40.1, 67.8, 101.0, 124.4, 125.4, 128.3, 128.5, 128.5, 144.1, 147.6, 149. HRMS (DART-TOF) *m/z* calcd for C₁₈H₁₉NO₄ [M + H]⁺ 314.1392, found 314.1395.

***r*-2-*p*-Nitrophenyl-*cis*-4,*cis*-6-dimethyl-2-phenyl-1,3-dioxane (2).** R_f = 0.27 (5% Et₂O / hexanes); mp 142 – 143 °C (30% Et₂O / hexanes); ¹H NMR (400 MHz, CDCl₃) δ 1.33 (d, *J* = 6.16 Hz, 6H), 1.39 – 1.54 (m, 2H), 3.99 – 4.08 (m, 2H), 7.28 (t, *J* = 7.33, 1H), 7.39 (t, *J* = 7.49, 2H), 7.50 (d, *J* = 7.12 Hz, 2H), 7.75 (d, *J* = 9.00 Hz, 2H), 8.10 (d, *J* = 9.04 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 21.9, 40.2, 67.6, 100.9, 123.5, 126.6, 127.3, 128.4, 129.3, 140.3, 147.3, 152.0. HRMS (DART-TOF) *m/z* calcd for C₁₈H₁₉NO₄ [M + H]⁺ 314.1392, found 314.1362.

***r*-2-*p*-Nitrophenyl-*cis*-4,*trans*-6-dimethyl-2-phenyl-1,3-dioxane.** R_f = 0.39 (5% Et₂O / hexanes); mp 108.5 – 110 °C (30% Et₂O / hexanes); ¹H NMR (400 MHz, CDCl₃) δ 1.31 (d, *J* = 2.24 Hz, 3H), 1.33 (d, *J* = 2.24 Hz, 3H), 1.71 (t, *J* = 7.68, 2H), 3.81 – 3.90 (m, 1H), 3.90 – 3.97 (m, 1H), 7.27 (t, *J* = 3.57, 1H), 7.33 (t, *J* = 7.38 Hz, 2H), 7.59 (d, *J* = 7.61 Hz), 7.78 (d, *J* = 8.88 Hz), 8.15 (d, *J* = 8.86

Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 21.5, 21.5, 41.2, 64.5, 64.7, 100.7, 123.5, 126.0, 127.0, 128.2, 128.4, 143.1, 147.4, 151.8. HRMS (DART-TOF) m/z calcd for $\text{C}_{18}\text{H}_{19}\text{NO}_4$ $[\text{M} + \text{H}]^+$ 314.1392, found 314.1396.

***r*-2-*p*-Methoxyphenyl-*trans*-4,*trans*-6-dimethyl-2-phenyl-1,3-dioxane (3) and *r*-2-*p*-Methoxyphenyl-*cis*-4,*cis*-6-dimethyl-2-phenyl-1,3-dioxane (4).** A mixture of 7.63 g (73.3 mmol) of 2,4-pentanediol, consisting of ~60% *meso* and ~40% racemic isomers, 7.18 g (38.8 mmol) of *p*-methoxybenzophenone and 200 mg (1.05 mmol) of *p*-TsOH in 50 mL of cyclohexane was heated at reflux under a Dean-Stark trap for 12 h, at which point the theoretical amount of water had collected in the trap. The reaction mixture was allowed to cool to room temperature, 0.5 g of anhydrous Na_2CO_3 was added to the filtrate, and the mixture was stirred for 1 h to neutralize any residual acid. The reaction was worked up as described above to yield 10.47 g (90.5%) of a clear, light yellow oil as a mixture of three diastereomers. A 1.50 g portion of the product mixture was purified by flash chromatography on 60 g of silica gel using a 0 - 15% Et_2O / hexanes gradient; the fractions were collected over anhydrous Na_2CO_3 to prevent epimerization of the isomers. Two fractions were collected from the sample: 118 mg (7.9%) of **3** as white crystals, and 285 mg (19%) of **4** as white crystals; the diastereomer resulting from condensation of the ketone with racemic 2,4-pentanediol was not collected, and was not further characterized, as it was not of interest. The epimers, **3** and **4** were distinguished using two-dimensional ^1H NOESY techniques. Each of the solid isomers were recrystallized, as described below, to give analytical samples used in the equilibration and crystallographic studies.

***r*-2-*p*-Methoxyphenyl-*trans*-4,*trans*-6-dimethyl-2-phenyl-1,3-dioxane (3).** R_f = 0.41 (5% Et_2O / hexanes); mp 91.9 – 92.5 °C (pentane); ^1H NMR (400 MHz, CDCl_3) δ 1.33 (d, J = 6.16 Hz, 6H), 1.40 – 1.49 (m, 2H), 3.82 (s, 3H), 3.99 – 4.07 (m, 2H), 6.93 (d, J = 8.62 Hz, 2H), 7.19 (t, J = 7.28 Hz, 1H), 7.27 (t, J = 7.68 Hz, 2H), 7.44 (d, J = 8.68 Hz, 2H), 7.53 (d, J = 7.70 Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 22.0, 40.4, 55.4, 67.1, 101.7, 114.3, 125.6, 127.7, 128.1, 128.9, 133.3, 145.8, 159.2. HRMS (DART-TOF) m/z calcd for $\text{C}_{19}\text{H}_{22}\text{O}_3$ $[\text{M} + \text{H}]^+$ 299.1647, found 299.1654.

***r*-2-*p*-Methoxyphenyl-*cis*-4,*cis*-6-dimethyl-2-phenyl-1,3-dioxane (4).** $R_f = 0.33$ (5% Et₂O / hexanes); mp 101.2 – 102.5 °C (pentane); ¹H NMR (400 MHz, CDCl₃) δ 1.30 (d, $J = 6.20$ Hz, 6H), 1.36 – 1.46 (m, 2H), 3.73 (s, 3H), 3.94 – 4.02 (m, 2H), 6.78 (d, $J = 8.80$ Hz, 2H), 7.27 (t, $J = 7.36$ Hz, 1H), 7.38 (t, $J = 7.80$ Hz, 2H), 7.41 (d, $J = 8.96$ Hz, 2H), 7.50 (d, $J = 7.80$ Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 22.0, 40.3, 55.4, 67.3, 101.8, 113.5, 127.1, 127.7, 127.7, 128.9, 138.2, 141.4, 159.2. HRMS (DART-TOF) m/z calcd for C₁₉H₂₂O₃ [M + H]⁺ 299.1647, found 299.1654.

***r*-2-*p*-Methoxyphenyl-*trans*-4,*trans*-6-dimethyl-2-*p*-nitrophenyl-1,3-dioxane (5) and *r*-2-*p*-Methoxyphenyl-*cis*-4,*cis*-6-dimethyl-2-*p*-nitrophenyl-1,3-dioxane (6).** A mixture of 7.01 g (67.40 mmol) of 2,4-pentanediol, consisting of ~60% *meso* and ~40% racemic isomers, 7.98 g (31.05 mmol) of 4-methoxy-4'-nitrobenzophenone³ and 150 mg of Amberlyst-15TM resin in 100 mL of cyclohexane was heated at reflux under a Dean-Stark trap for 3 d, at which point the theoretical amount of water had collected in the trap. The reaction mixture was worked up as described above to give 5.87 g (55%) of a clear, light yellow oil as a mixture of three diastereomers. A 400 mg portion of the product mixture was absorbed on 1 g of silica gel and this sample was loaded on 65 g of silica. Column chromatography was performed by slowly increasing the volumetric ratio of ether to hexanes from 0% to 7% Et₂O / hexanes; 46 fractions (15 - 20 mL each) were collected once material began eluting from the column. Fractions 18 - 34 yielded 100 mg (25%) of **5** as a waxy, white solid. Fractions 38 - 46 yielded 99 mg (25%) of **6** as a waxy, white solid. The fractions containing the diastereomer resulting from condensation of the ketone with racemic 2,4-pentanediol were not further characterized. After concentration of the chromatographic fractions, pure samples of epimers **5** and **6** were obtained by fractional sublimation at 1 mm (**6** sublimes between 135 – 141 °C; **5** sublimes between 150 – 158 °C) followed by resublimation of each compound. The isomers were distinguished utilizing two-dimensional ¹H NOESY techniques as detailed in the Experimental Section. Each of the solid isomers were recrystallized, as described below, to give analytical samples used in the equilibration studies.

***r*-2-*p*-Methoxyphenyl-*trans*-4,*trans*-6-dimethyl-2-*p*-nitrophenyl-1,3-dioxane (5).** $R_f = 0.15$ (5% Et₂O / hexanes); mp 157.4 – 158.2 °C (resublimation), 156.1 - 157.1 °C (recrystallized from 3% Et₂O / hexanes); ¹H NMR (400 MHz, CDCl₃) δ 1.32 (d, $J = 6.16$ Hz, 6H), 1.41 – 1.53 (m, 2H), 3.80 (s, 3H), 4.00 – 4.08 (m, 2H), 6.91 (d, $J = 8.80$ Hz, 2H), 7.40 (d, $J = 8.80$ Hz, 2H), 7.73 (d, $J = 9.00$ Hz, 2H), 8.10 (d, $J = 9.00$ Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 21.9, 40.3, 55.5, 67.4, 100.8, 114.7, 123.5, 126.5, 128.7, 132.2, 147.3, 152.3, 159.6. HRMS (DART-TOF) m/z calcd for C₁₉H₂₁NO₅ [M + H]⁺ 344.1498, found 344.1498.

***r*-2-*p*-Methoxyphenyl-*cis*-4,*cis*-6-dimethyl-2-*p*-nitrophenyl-1,3-dioxane (6).** $R_f = 0.24$ (5% Et₂O / hexanes) mp 141.4 – 142.4 °C (resublimation); 137.8 - 139.1 °C (recrystallized from 3% Et₂O / hexanes); ¹H NMR (400 MHz, CDCl₃) δ 1.34 (d, $J = 6.16$ Hz, 6H), 1.42 – 1.53 (m, 2H), 3.73 (s, 3H), 3.84 – 3.93 (m, 2H), 6.80 (d, $J = 8.96$ Hz, 2H), 7.43 (d, $J = 8.96$ Hz, 2H), 7.67 (d, $J = 8.86$ Hz, 2H), 8.23 (d, $J = 8.86$ Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 21.9, 40.0, 55.4, 67.8, 101.0, 113.7, 124.3, 126.8, 128.4, 136.7, 147.4, 149.5, 159.5. HRMS (DART-TOF) m/z calcd for C₁₉H₂₁NO₅ [M + H]⁺ 344.1498, found 344.1501.

***r*-2-(3,4,5)-Trifluorophenyl-*trans*-4, *trans*-6-dimethyl-2-phenyl-1,3-dioxane (7) and *r*-2-(3,4,5)-Trifluorophenyl-*cis*-4, *cis*-6-dimethyl-2-phenyl-1,3-dioxane (8).** A mixture of 1.45 g (14.0 mmol) of 2,4-pentanediol, consisting of ~60% *meso* and ~40% racemic isomers, 3.00 g (12.7 mmol) of 3,4,5-trifluorobenzophenone and 125 mg (0.656 mmol) of *p*-TsOH in 25 mL of cyclohexane was heated at reflux under a Dean-Stark trap for 9 d, at which point the theoretical amount of water had collected in the trap. Due to competitive dehydration of the diol during the course of the sluggish condensation, it was necessary to add an additional 14.0 mmol of 2,4-pentanediol on day 6. The reaction mixture was allowed to cool to room temperature, 0.5 g of anhydrous Na₂CO₃ was added to the filtrate, and the mixture was stirred for 1 h to neutralize any residual acid. The reaction was worked up as described above to yield 3.61 g (93%) of a white solid as a mixture of three diastereomers. Separation of compounds **7** and **8** was achieved by preparative TLC of a 50 mg portion of the mixture on a 1000 μm SiO₂ glass-backed plate

using a 1% solution of Et₂O in hexanes as eluent: **7**, R_f = 0.47; **8**, R_f = 0.53. From this sample, 8 mg, (16%) of **7** and 10 mg of **8** (20%) were isolated as a white solids. There was no attempt made to separate the diastereomer resulting from condensation of the ketone with racemic 2,4-pentanediol, as it was not of interest. The epimers, **7** and **8** were distinguished using two-dimensional ¹H NOESY techniques as detailed in the Experimental Section. Each of the solid isomers were recrystallized, as described below, to give analytical samples used in the equilibration studies.

***r*-2-(3,4,5)-Trifluorophenyl-*trans*-4, *trans*-6-dimethyl-2-phenyl-1,3-dioxane (7).** Mp 109.3 – 110.5 °C (pentane); ¹H NMR (400 MHz, CDCl₃) δ 1.32 (d, *J* = 6.10 Hz, 6H), 1.40 – 1.56 (m, 2H), 3.89 – 3.97 (m, 2H), 7.12 (dd, *J* = 6.8 Hz, *J* = 8.2, 2H), 7.22 (t, *J* = 7.2 Hz, 1H) 7.28 (t, *J* = 7.2, 2H), 7.44 (d, *J* = 7.3, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 21.9, 40.0, 67.7, 100.5, 111.6 (dd, *J* = 16.1 Hz, *J* = 6.0 Hz), 125.3, 128.3, 128.4, 138.5 (q, *J* = 5.5 Hz), 139.2 (dt, *J* = 250.0 Hz, *J* = 16.0 Hz), 144.3, 151.9 (ddd, *J* = 251.0 Hz, *J* = 10.3 Hz, *J* = 3.4 Hz); ¹⁹F NMR (376 MHz, CDCl₃) δ –133.6 (dd, *J* = 20.4, 8.2 Hz), –161.8 (tt, *J* = 20.4, 6.8 Hz). HRMS (DART-TOF) *m/z* calcd for C₁₈H₁₇F₃O₂ [M + H]⁺ 323.1259, found 323.1245.

***r*-2-(3,4,5)-trifluorophenyl-*cis*-4, *cis*-6-dimethyl-2-phenyl-1,3-dioxane (8).** Mp 99.1 – 99.8 °C (pentane); ¹H NMR (400 MHz, CDCl₃) δ 1.31 (d, *J* = 6.20 Hz, 6H), 1.36 – 1.51 (m, 2H), 3.94 – 4.02 (m, 2H), 7.17 (dd, *J* = 6.80 Hz, *J* = 8.8 Hz, 2H), 7.30 (t, *J* = 7.46 Hz, 1H) 7.40 (t, *J* = 7.40, 2H), 7.45 (d, *J* = 8.28, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 21.9, 40.1, 67.6, 100.4, 110.1 (dd, *J* = 16.1 Hz, *J* = 6.0 Hz), 127.3, 128.4, 129.3, 139.3 (dt, *J* = 250.0 Hz, *J* = 16.0 Hz), 140.1, 141.8 (q, *J* = 6.0 Hz), 150.9 (ddd, *J* = 248.6 Hz, *J* = 10.3 Hz, *J* = 3.4 Hz); ¹⁹F NMR (376 MHz, CDCl₃) δ –135.2 (dd, *J* = 20.4, 8.8 Hz), –162.8 (tq, *J* = 20.4, 6.8 Hz). HRMS (DART-TOF) *m/z* calcd for C₁₈H₁₇F₃O₂ [M + H]⁺ 323.1259, found 323.1287.

Equilibrations

For each pair of epimeric 2,2-diaryl-*cis*-4,6-dimethyl-1,3-dioxanes equilibrium was approached independently from pure samples of each isomer. The epimers were equilibrated at room temperature

(~23 °C) in sealed vials or ampoules as solutions in cyclohexane, Et₂O, and CH₃CN over Amberlyst-15 resin (20 – 30 beads). Periodically samples were opened and neutralized by shaking with anhydrous K₂CO₃. The area ratio of the isomers was then determined by GC analysis using one of the following columns: a 30 m x 0.25 mm x 0.25 μm Optima-225 50% cyanopropyl / 50% phenylmethyl polysiloxane column or a 30 m x 0.25 mm x 0.25 μm EC-1 100% dimethyl polysiloxane. The analysis parameters are detailed below. When the same area ratios were obtained from initially pure samples of each epimer, it was deemed that equilibrium had been attained. Area ratios for each equilibrium were taken as the average of 8 – 22 determinations from each side. The equilibrium constant for a system was calculated from the area ratio of that system and the free-energy difference was evaluated as $\Delta G^\circ = -RT \ln K$ (Table 1-1). All reported errors (Table 1-1) are propagated standard deviations.⁴

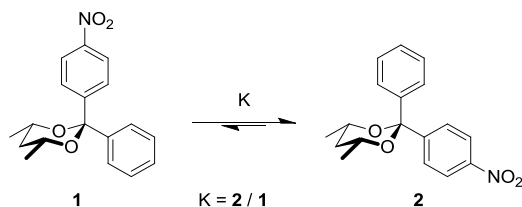
X-ray Crystallography

All structures were solved by direct methods using SHELXS and refined against F^2 on all data by full-matrix least squares with SHELXL.⁵ All non-hydrogen atoms were refined anisotropically. Hydrogen atoms were included in the model at geometrically calculated positions and refined using a riding model. The isotropic displacement parameters of all hydrogen atoms were fixed to 1.2 times the U value of the atoms to which they are linked (1.5 times for methyl groups). The full numbering scheme of compounds **1**, **2**, **3**, and **4** can be found below. Full details of the X-ray structure determination are located in the CIF. Additionally, CCDC numbers 1050759 (**1**), 1050760 (**2**), 1050761 (**3**), and 1050762 (**4**) contain the supplementary crystallographic data for this work.⁶

Calculations

The calculations and the Hirshfeld charge calculations were carried out using Gaussian-09.⁷

Gas Chromatography Parameters, Representative Chromatograms, and Equilibration Data



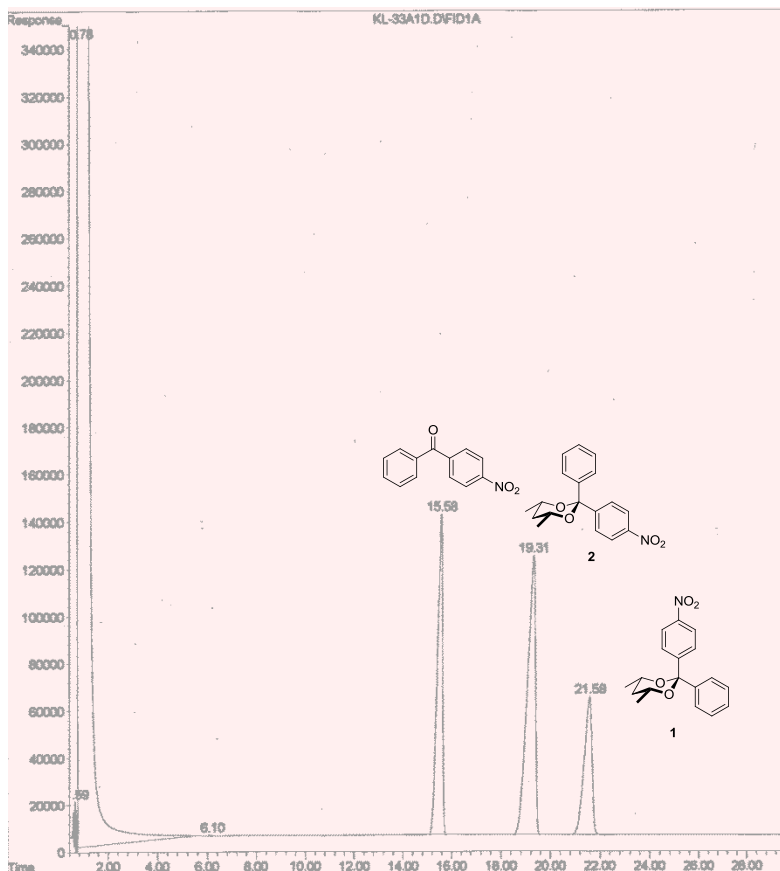
GC Column: OPTIMA[®] 225; 50% cyanopropyl, 5 a consequence 0% phenylmethyl polysiloxane ; 30 meters; id-0.25mm; film- 0.25 μ m

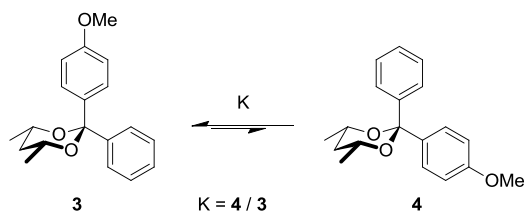
Program Description:

The initial temperature was set at 200 °C for five minutes and increased at a rate of 3 °C/min and held at a final temperature of 227 °C for a period of 45 min.

Compound	Ret. Time
1	21.6 min
2	19.3 min
<i>p</i> -nitrobenzophenone	15.6 min

* Equilibration in cyclohexane was never fully reached even after 18 months due to the instability of the required carbocation intermediate in a non-polar solvent.



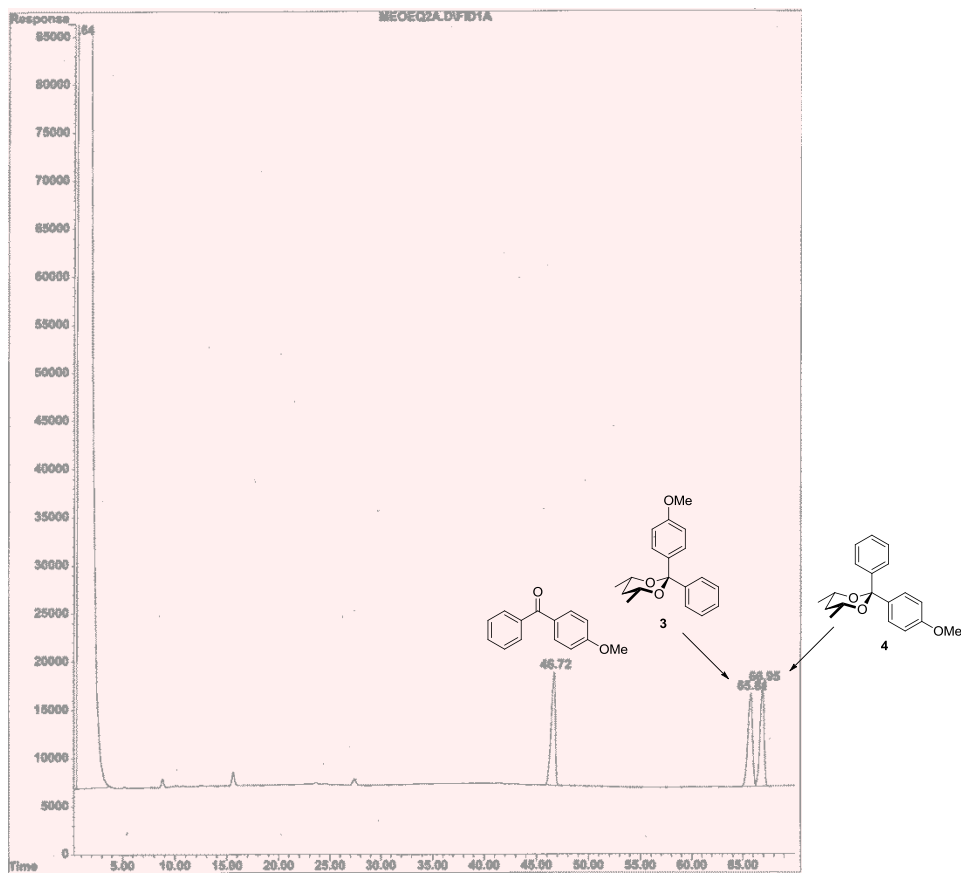


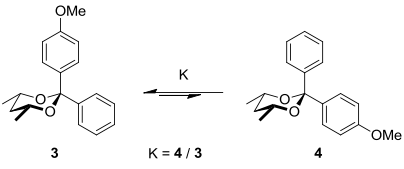
GC Column: EC-1; 100% dimethyl polysiloxane; 30 meters; id- 0.25mm; film- 0.25 μ m

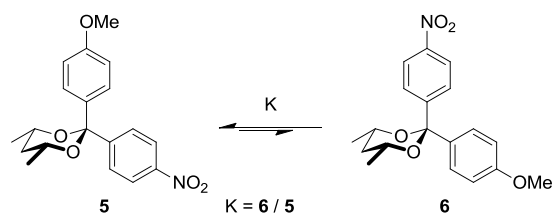
Program Description:

The initial temperature was set at 100 °C for five minutes and increased at a rate of 1 °C/min and held at a final temperature of 210 °C for a period of 20 min.

Compound	Ret. Time
3	65.8 min
4	66.9 min
<i>p</i> -methoxybenzophenone	46.7 min



									
Equilibrium study from <i>r</i> -2- <i>p</i> -Methoxyphenyl- <i>trans</i> -4, <i>trans</i> -6-dimethyl-2-phenyl-1,3-dioxane 3 in cyclohexane									
Area of axial <i>p</i> -OMe isomer (3)	Area of equatorial <i>p</i> -OMe isomer (4)	K	K _{av}	Overall \bar{K}	(K - \bar{K}) ²	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
1538670	1350638	0.877796	0.8687384	0.873381	1.9493E-05	0.007475	0.004675104	0.0796773	0.080 +/- 0.003 kcal/mol
3466720	2968557	0.856301			0.0002917			0.0765353	0.003141925
3276718	2773396	0.846394			0.00072826			0.0828361	0.003158789
1711441	1494807	0.87342			1.5525E-09				
1823190	1534738	0.841787			0.00099815				
1202466	1082988	0.900639			0.00074302				
1318632	1153151	0.874506			1.2652E-06				
1497769	1316634	0.879063			3.2294E-05				
Equilibrium study from <i>r</i> -2- <i>p</i> -Methoxyphenyl- <i>cis</i> -4, <i>cis</i> -6-dimethyl-2-phenyl-1,3-dioxane 4 in cyclohexane									
Area of axial <i>p</i> -OMe isomer (3)	Area of equatorial <i>p</i> -OMe isomer (4)	K	K _{av}		(K - \bar{K}) ²				
4595440	3987246	0.867653	0.876757		3.281E-05				
5288487	4797713	0.9072			0.00114371				
3192742	2705050	0.84725			0.00068283				
2152672	1822780	0.846752			0.00070907				
2193693	1870554	0.852696			0.00042784				
1135759	1007406	0.886989			0.00018519				
1146904	1014806	0.884822			0.00013091				
1178622	1033254	0.876663			1.0772E-05				
1277048	1129513	0.884472			0.00012301				
3039024	2683252	0.882932			9.123E-05				
1845240	1673444	0.906898			0.00112339				
Equilibrium study from <i>r</i> -2- <i>p</i> -Methoxyphenyl- <i>trans</i> -4, <i>trans</i> -6-dimethyl-2-phenyl-1,3-dioxane 3 in ether									
Area of axial <i>p</i> -OMe isomer (3)	Area of equatorial <i>p</i> -OMe isomer (4)	K	K _{av}	Overall \bar{K}	(K - \bar{K}) ²	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
2261773	2139692	0.946024	0.9387625	0.938049	6.36E-05	0.000502	0.002995082	0.0376381	0.038 +/- 0.002 kcal/mol
2045575	1945501	0.951078			0.00016974			0.035762	0.001876111
2496703	2307793	0.924336			0.00018805			0.0395202	0.001882111
2543537	2374676	0.933612			1.9691E-05				
Equilibrium study from <i>r</i> -2- <i>p</i> -Methoxyphenyl- <i>cis</i> -4, <i>cis</i> -6-dimethyl-2-phenyl-1,3-dioxane 4 in ether									
Area of axial <i>p</i> -OMe isomer (3)	Area of equatorial <i>p</i> -OMe isomer (4)	K	K _{av}		(K - \bar{K}) ²				
3620844	3394860	0.937588	0.9373359		2.1269E-07				
4062241	3798773	0.935142			8.4507E-06				
3427135	3198150	0.933185			2.3663E-05				
3024824	2853706	0.943429			2.894E-05				
Equilibrium study from <i>r</i> -2- <i>p</i> -Methoxyphenyl- <i>trans</i> -4, <i>trans</i> -6-dimethyl-2-phenyl-1,3-dioxane 3 in acetonitrile									
Area of axial <i>p</i> -OMe isomer (3)	Area of equatorial <i>p</i> -OMe isomer (4)	K	K _{av}	Overall \bar{K}	(K - \bar{K}) ²	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
2042572	2125709	1.040702	1.0406511	1.03939	1.7214E-06	0.00084	0.003416622	-0.022737	-0.023 +/- 0.002 kcal/mol
1746410	1793200	1.026792			0.00015871			-0.024669	-0.001931406
1645594	1730726	1.051733			0.00015235			-0.0208	0.001937765
1659682	1731674	1.043377			1.5895E-05				
Equilibrium study from <i>r</i> -2- <i>p</i> -Methoxyphenyl- <i>cis</i> -4, <i>cis</i> -6-dimethyl-2-phenyl-1,3-dioxane 4 in acetonitrile									
Area of axial <i>p</i> -OMe isomer (3)	Area of equatorial <i>p</i> -OMe isomer (4)	K	K _{av}		(K - \bar{K}) ²				
2485216	2568152	1.033372	1.0383813		3.622E-05				
2212059	2261786	1.02248			0.00028595				
2288022	2407738	1.052323			0.00016726				
2244962	2343996	1.044114			2.2314E-05				
2124704	2208880	1.039618			5.1833E-08				



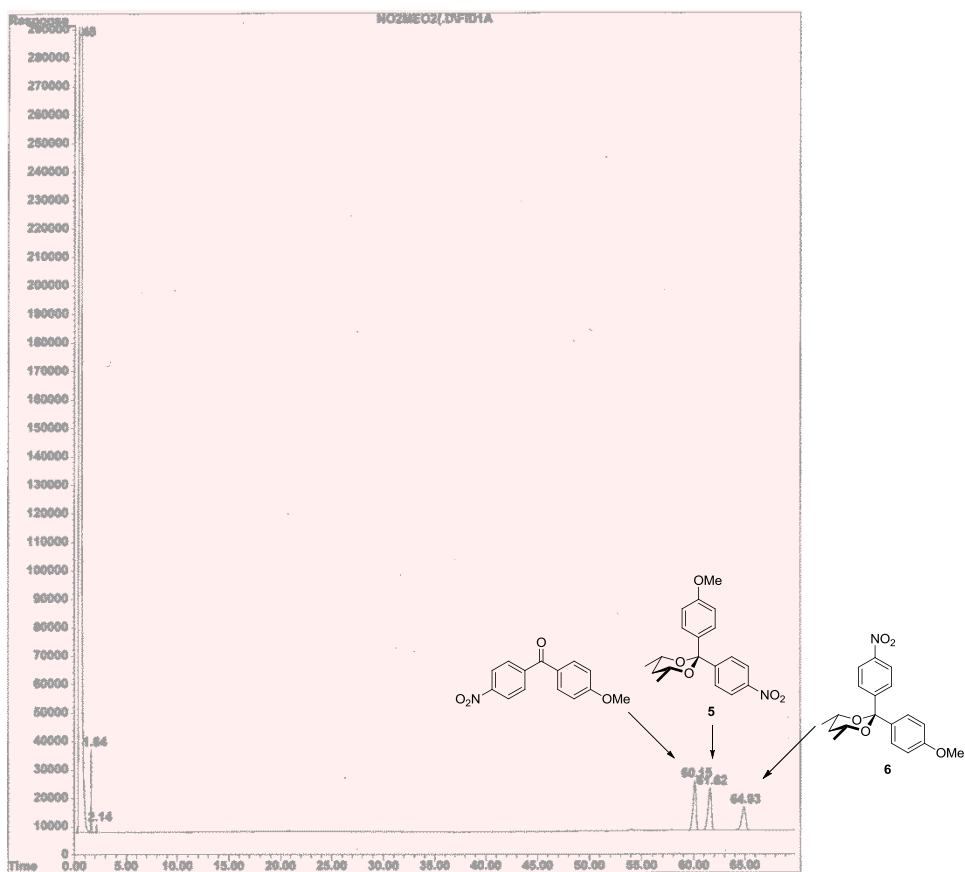
GC Column: OPTIMA[®] 225; 50% cyanopropyl, 50% phenylmethyl polysiloxane; 30 meters; id- 0.25mm; film- 0.25 μ m

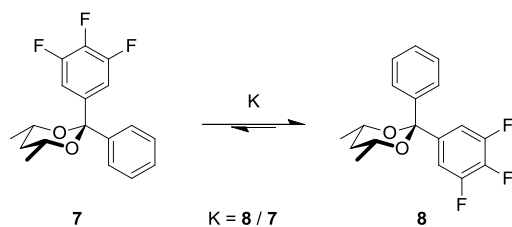
Program Description:

The initial temperature was set at 185 °C for fifteen minutes and increased at a rate of 3 °C/min and held at a final temperature of 227 °C for a period of 45 min.

Compound	Ret. Time
5	61.6 min
6	64.9 min
4-methoxyphenyl-4-nitrophenylmethanone	60.1 min

* Differences in the solubility of **5** and **6** in cyclohexane complicate any equilibration studies. At 40 mg/mL in cyclohexane **5** is fully soluble, whereas **6** is mostly insoluble. This would lead to an over-estimation of the stability of **5** in cyclohexane, as **5** would always be present to a greater extent than **6** due to differing solubility.





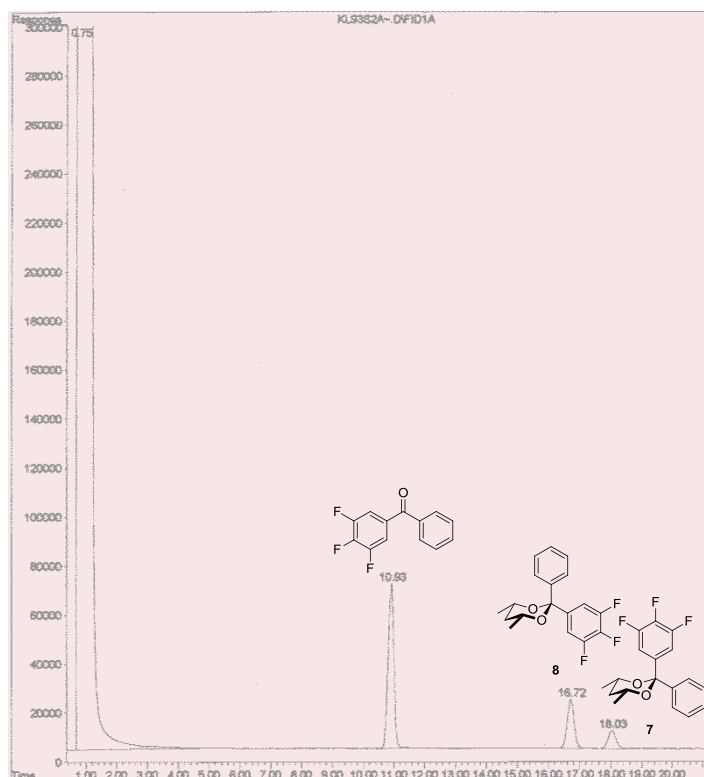
GC Column: OPTIMA[®] 225; 50% cyanopropyl, 50% phenylmethyl polysiloxane ; 30 meters; id- 0.25mm; film- 0.25 μ m

Program Description:

The initial temperature was set at 140 °C for five minutes and increased at a rate of 3 °C/min and held at a final temperature of 170 °C for a period of 15 min.

Compound	Ret. Time
7	18.0 min
8	16.7 min
3,4,5-trifluorobenzophenone	10.9 min















* Due to the complexity of separation, instead of starting with 100% pure **7** or **8**, *cis*-enriched (**8**) and *trans*-enriched (**7**) samples were obtained by preparative TLC and removed from the silica gel with the solvent to be used for the equilibration study. The starting ratio was determined by GC analysis, and equilibrium was deemed reached after each pair of samples contained the same area ratio over a period of time.







Equilibrium study from <i>r</i> -2-3,4,5-trifluorophenyl- <i>cis</i> -4, <i>cis</i> -6-dimethyl-2-phenyl-1,3-dioxane 8 in acetonitrile									
Area of axial trifluoro isomer (7)	Area of equatorial trifluoro isomer (8)	K	K _{Av}	Overall \bar{K}	$(K - \bar{K})^2$	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
3357185	4010318	1.194548	1.2053785	1.186284	6.8287E-05	0.036852	0.008931198	-0.100536	-0.101+/-0.004 kcal/mol
1377887	1737321	1.260859			0.00556138			-0.10495	0.004414273
2635394	3103219	1.177516			7.6879E-05			-0.096088	-0.004447633
1460367	1823519	1.248672			0.00389221				
3134693	3747860	1.195607			8.6909E-05				
2245214	2740891	1.22077			0.00118931				
5511749	6616676	1.200468			0.00020117				
3924978	4701418	1.19782			0.00013308				
3353096	4010623	1.196095			9.6262E-05				
4877950	5683261	1.165092			0.0004491				
3382047	4064263	1.201717			0.00023817				
Equilibrium study from <i>r</i> -2-3,4,5-trifluorophenyl- <i>trans</i> -4, <i>trans</i> -6-dimethyl-2-phenyl-1,3-dioxane 7 in acetonitrile									
Area of axial trifluoro isomer (7)	Area of equatorial trifluoro isomer (8)	K	K _{Av}		$(K - \bar{K})^2$				
2734098	3231658	1.181983	1.1671898		1.8498E-05				
1447368	1628140	1.124897			0.00376838				
982222	1214986	1.236977			0.00256976				
1246918	1514673	1.214733			0.00080936				
1278005	1403789	1.098422			0.00771974				
1300518	1459894	1.122548			0.00406229				
1694817	2004644	1.182809			1.208E-05				
2150572	2447621	1.138126			0.00231925				
2593395	2931076	1.130208			0.00314453				
936140	1131046	1.208202			0.00048038				
2036569	2444256	1.200183			0.00019318				






Relevant Calculated Energies for Selected Benzophenone Ketals











(B3LYP/6-311+G* opt=verytight int=ultrafine)⁸

compound	E(0)	E(298)	H(298)	G(298)	molecular dipole moment (D)	$\Delta E(0)$	$\Delta E(298)$	ΔH values at 298K (kcal/mol)	ΔG values at 298K (kcal/mol)
	-825.019922	-825.004070	-825.003125	-825.063626	2.750	-0.31	-0.31	-0.30	-0.37
	-825.019434	-825.003583	-825.002639	-825.063030	0.983				
	-884.186294	-884.169324	-884.168380	-884.231870	2.887	-0.06	-0.06	-0.07	-0.06
	-884.186193	-884.169221	-884.168276	-884.231772	2.031				
	-868.943073	-868.927890	-868.926945	-868.986403	2.189	0.24	0.25	0.25	0.17
	-868.943461	-868.928292	-868.927348	-868.986668	4.118				
	-1229.298735	-1229.283141	-1229.282197	-1229.343007	2.248	0.28	0.28	0.28	0.20
	-1229.299174	-1229.283592	-1229.282648	-1229.343332	4.436				
	-1106.811839	-1106.793804	-1106.792860	-1106.860632	3.190	0.43	0.43	0.43	0.51
	-1106.812526	-1106.794487	-1106.793543	-1106.861451	5.895				
	-1067.485523	-1067.468509	-1067.467565	-1067.531239	3.478	0.50	0.52	0.52	0.43
	-1067.486321	-1067.469341	-1067.468397	-1067.531930	6.089				
	-861.934598	-861.918425	-861.917488	-861.979331	4.773	0.51	0.53	0.52	0.42
	-861.935415	-861.919262	-861.918324	-861.979993	7.633				

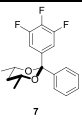
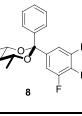
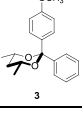
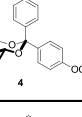
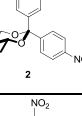
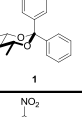
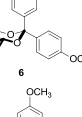
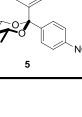
	-974.227864	-974.210918	-974.209973	-974.274215	5.073	0.67	0.67	0.67	0.64
	-974.228931	-974.211992	-974.211048	-974.275238	7.960				
	-968.210188	-968.194122	-968.193178	-968.254525	2.882	-1.30	-1.29	-1.29	-1.41
	-968.208113	-968.192062	-968.191117	-968.252275	1.067				
	-1067.485523	-1067.468509	-1067.467565	-1067.531239	3.478	0.50	-0.99	0.52	0.45
	-1067.486321	-1067.466934	-1067.468397	-1067.531960	6.089				
	-1266.011964	-1265.993091	-1265.992147	-1266.059715	2.568	-0.85	-0.85	-0.85	-0.89
	-1266.010604	-1265.991741	-1265.990797	-1266.058289	4.865				
	-1029.583674	-1029.565200	-1029.564256	-1029.631705	6.324	1.00	1.01	1.01	1.00
	-1029.585275	-1029.566811	-1029.565867	-1029.633300	8.014				
	-1088.750076	-1088.730483	-1088.729538	-1088.799991	5.333	0.77	0.78	0.78	0.74
	-1088.751308	-1088.731725	-1088.730781	-1088.801171	8.408				
	-769.664379	-769.650037	-769.649093	-769.706543					

Relevant Calculated Energies for Selected 2,2-diaryl-*cis*-4,6-dimethyl-1,3-dioxanes (B3LYP/6-311+G* opt=verytight int=ultrafine)⁹

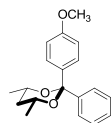
compound	E(0)	E(298)	H(298)	G(298)	molecular dipole moment (D)	$\Delta E(0)$	$\Delta E(298)$	ΔH values at 298K (kcal/mol)	ΔG values at 298K (kcal/mol)
	-962.786466	-962.766386	-962.765442	-962.835475	2.867	-0.07	-0.07	-0.07	-0.05
	-962.786362	-962.766279	-962.765335	-962.835394	2.037				
	-947.543293	-947.524997	-947.524053	-947.590107	2.287	0.26	0.26	0.26	0.24
	-947.543703	-947.525415	-947.524471	-947.590489	4.151				
	-1307.898984	-1307.880284	-1307.879340	-1307.946664	2.364	0.24	0.25	0.24	0.24
	-1307.899368	-1307.880675	-1307.879730	-1307.947041	4.387				
	-1344.612919	-1344.590932	-1344.589908	-1344.664166	2.686	-1.13	-1.12	-1.07	-1.22
	-1344.611120	-1344.589140	-1344.588196	-1344.662221	4.895				
	-1046.810703	-1046.791588	-1046.790643	-1046.858048	2.843	-1.40	-1.43	-1.43	-1.29
	-1046.808464	-1046.789315	-1046.788371	-1046.855991	1.042				
	-1146.085873	-1146.065750	-1146.064806	-1146.134986	3.633	0.53	0.54	0.54	0.55
	-1146.086710	-1146.066610	-1146.065666	-1146.135864	6.151				

	-1052.828202	-1052.808148	-1052.807204	-1052.877887	5.255	0.65	0.66	0.66	0.72
	-1052.829242	-1052.809193	-1052.808249	-1052.879041	8.037				
	-1185.412100	-1185.390950	-1185.390005	-1185.464355	3.334	0.38	0.39	0.39	0.43
	-1185.412711	-1185.391566	-1185.390621	-1185.465037	5.949				
	-903.619987	-903.601021	-903.600008	-903.667136	2.701	-0.26	-0.26	-0.22	-0.21
	-903.619577	-903.600604	-903.599660	-903.666795	1.036				
	-940.534926	-940.515651	-940.514707	-940.583049	4.939	0.54	0.55	0.55	0.53
	-940.535790	-940.516526	-940.515582	-940.583900	7.702				
	-1167.350404	-1167.327696	-1167.326752	-1167.403774	6.371	0.72	0.73	0.73	0.62
	-1167.351544	-1167.328853	-1167.327909	-1167.404765	8.457				

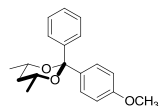
Calculated B3LYP/6-311+G* Solvent Effects Tight Optimization for 2,2-Diaryl-*cis*-4,6-dimethyl-1,3-dioxanes

substituent position	solvent	E(0)	E(298)	H(298)	G(298)	$\Delta E(0)$	$\Delta E(298)$	ΔH values (kcal/mol) at 298K	ΔG values (kcal/mol) at 298K
 7	gas phase	-1146.085873	-1146.065750	-1146.064806	-1146.134986	0.53	0.54	0.54	0.55
	cyclohexane	-1146.089333	-1146.069202	-1146.068258	-1146.138482	0.48	0.49	0.49	0.49
	ether	-1146.092118	-1146.071986	-1146.071042	-1146.141224	0.39	0.40	0.40	0.39
	acetonitrile	-1146.095470	-1146.075329	-1146.074385	-1146.144584	0.17	0.18	0.18	0.12
 8	gas phase	-1146.086710	-1146.066610	-1146.065666	-1146.135864				
	cyclohexane	-1146.090098	-1146.069990	-1146.069046	-1146.139257				
	ether	-1146.092732	-1146.072617	-1146.071673	-1146.141848				
	acetonitrile	-1146.095741	-1146.075622	-1146.074677	-1146.144770				
 3	gas phase	-962.786466	-962.766386	-962.765442	-962.835475	-0.07	-0.07	-0.07	-0.05
	cyclohexane	-962.790208	-962.770122	-962.769177	-962.839360	-0.10	-0.09	-0.09	-0.36
	ether	-962.793390	-962.773302	-962.772358	-962.842538	-0.12	-0.09	-0.09	-0.45
	acetonitrile	-962.797306	-962.777225	-962.776281	-962.846192	-0.11	-0.08	-0.08	-0.31
 4	gas phase	-962.786362	-962.766279	-962.765335	-962.835394				
	cyclohexane	-962.790041	-962.769982	-962.769038	-962.838793				
	ether	-962.793202	-962.773156	-962.772212	-962.841818				
	acetonitrile	-962.797138	-962.777098	-962.776154	-962.845695				
 2	gas phase	-1052.829242	-1052.809193	-1052.808249	-1052.879041	0.65	0.66	0.66	0.72
	cyclohexane	-1052.834136	-1052.814062	-1052.813118	-1052.884224	0.59	0.59	0.59	0.66
	ether	-1052.837904	-1052.817798	-1052.816854	-1052.888512	0.47	0.47	0.47	0.65
	acetonitrile	-1052.842078	-1052.821973	-1052.821029	-1052.892316	0.22	0.23	0.23	0.05
 1	gas phase	-1052.828202	-1052.808148	-1052.807204	-1052.877887				
	cyclohexane	-1052.833191	-1052.813115	-1052.812171	-1052.883168				
	ether	-1052.837149	-1052.817042	-1052.816098	-1052.887474				
	acetonitrile	-1052.841735	-1052.821602	-1052.820658	-1052.892243				
 6	gas phase	-1167.350404	-1167.327696	-1167.326752	-1167.403774	0.72	0.73	0.73	0.62
	cyclohexane	-1167.356155	-1167.333415	-1167.332471	-1167.409349	0.63	0.66	0.66	0.54
	ether	-1167.360598	-1167.337888	-1167.336944	-1167.413802	0.54	0.55	0.55	0.46
	acetonitrile	-1167.365777	-1167.343039	-1167.342095	-1167.419227	0.29	0.31	0.31	0.13
 5	gas phase	-1167.351544	-1167.328853	-1167.327909	-1167.404765				
	cyclohexane	-1167.357159	-1167.334472	-1167.333528	-1167.410207				
	ether	-1167.361466	-1167.338767	-1167.337823	-1167.414535				
	acetonitrile	-1167.366236	-1167.343528	-1167.342583	-1167.419427				

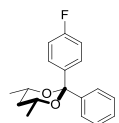
X,Y,Z atom coordinates of calculated structures



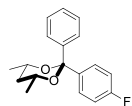
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C	-1.21241200	-2.23596000	-1.18596700
C	-1.67527400	-2.89688900	0.11061000
H	0.06006100	-2.36295800	1.26302100
H	-0.13146500	-2.39742200	-1.30156700
H	-2.76577700	-2.82369000	0.19090300
H	-1.40715700	-3.95927300	0.10617000
O	-1.46124700	-0.82049400	-1.11217800
O	-1.28235500	-0.78585300	1.22779900
C	0.63618400	-0.06735100	-0.10798700
C	1.44052800	0.03013500	1.02494500
C	1.25539900	0.00943200	-1.36230100
C	2.82519700	0.18409200	0.92789900
H	0.98497100	-0.01233400	2.00790900
C	2.62896400	0.16145400	-1.47744700
H	0.65077600	-0.05032000	-2.26017700
C	3.42691900	0.24937400	-0.33066800
H	3.41281600	0.25303800	1.83489500
H	3.10690800	0.21793500	-2.44940800
C	-1.50169600	1.24843600	0.03728300
C	-1.85926400	1.88707000	-1.15244300
C	-1.66126900	1.92718300	1.24778500
C	-2.36652400	3.18496700	-1.13126400
H	-1.75587600	1.36182600	-2.09364000
C	-2.16897900	3.22471400	1.26731500
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H	-2.64566200	3.66687500	-2.06323000
H	-2.29373900	3.73774100	2.21600500
H	-2.91726600	4.87072500	0.09377100
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H	5.58948100	-0.38395900	1.20538200
H	6.63050200	0.62808000	0.17464700
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C	-1.93430000	-2.74212900	-2.42222800
H	-1.76574300	-3.81521000	-2.54977300
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C	-1.55685100	-2.66699400	2.64812300
H	-2.63303500	-2.49067900	2.72082700
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H	-1.06808600	-2.13212600	3.46594600



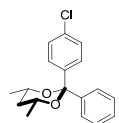
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C	2.78978700	-2.12551200	0.07603500
H	2.89695900	-0.43085100	1.39668200
H	3.05561800	-0.39272200	-1.16938700
H	2.28471100	-3.09699000	0.03045900
H	3.86841600	-2.30774600	0.13819700
O	1.06923100	-0.98250200	-1.18578500
O	0.92676800	-1.02386400	1.15687800
C	1.13083000	1.13869200	0.03417600
C	1.24456400	1.80182700	1.25956400
C	1.43016700	1.83881900	-1.13790000
C	1.66057000	3.13067000	1.31355400
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H	1.33577200	1.33966900	-2.09557500
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C	-0.92762100	-0.29423500	-0.12258800
C	-1.56012600	-0.17166000	-1.36573600
C	-1.71918000	-0.35838900	1.02020100
C	-2.94222500	-0.11551500	-1.45936000
H	-0.96463800	-0.13710600	-2.26960900
C	-3.11265200	-0.30230600	0.94062600
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H	3.79564900	-2.34172700	-2.54472400
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H	1.84444300	-3.06874800	2.54845100
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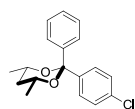
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C	0.63327200	3.11926900	0.00009200
H	-0.83948600	2.22162300	1.28462600
H	-0.83941000	2.22168200	-1.28457100
H	1.71208100	3.31136200	0.00012800
H	0.11789600	4.08602400	0.00009900
O	0.84002100	1.01280800	-1.17374900
O	0.83995100	1.01275300	1.17384700
C	-0.93031600	-0.19722600	-0.00003200
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H	-1.08891600	-0.27205900	2.14220100
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C	1.46839800	-0.94542500	0.00002200
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H	3.00537800	-3.08898800	-2.14709100
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H	3.72355200	-4.11312600	0.00001500
C	0.74561900	2.94947300	-2.54265700
H	0.31626100	3.94685800	-2.67244400
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H	1.83463300	3.03927400	2.53903600
H	0.31610500	3.94673400	2.67264700
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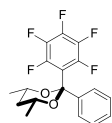
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C	-2.50616100	-2.08648000	0.00021800
H	-2.66287000	-0.36687900	-1.28118800
H	-2.66288300	-0.36659600	1.28124200
H	-2.01607500	-3.06654400	0.00032800
H	-3.58944800	-2.25012000	0.00023200
O	-0.69217000	-0.99621500	1.17348600
O	-0.69215900	-0.99647800	-1.17327600
C	-0.78319400	1.14943700	-0.00013200
C	-0.97592100	1.83498200	-1.20280900
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C	-1.36437500	3.17339000	-1.20400600
H	-0.82024300	1.31750300	-2.14257200
C	-1.36443200	3.17364000	1.20329400
H	-0.82034500	1.31794600	2.14227000
C	-1.56153600	3.84806600	-0.00043000
H	-1.51147800	3.68965300	-2.14757900
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C	1.24979000	-0.32803600	0.00004100
C	1.95766800	-0.31626200	1.20389800
C	1.95768300	-0.31655200	-1.20380900
C	3.35062000	-0.29172600	1.21204600
H	1.41969500	-0.34368800	2.14273600
C	3.35063500	-0.29201700	-1.21194500
H	1.41972200	-0.34420400	-2.14264700
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H	3.91123200	-0.28985900	-2.13976500
C	-2.30616800	-2.07058400	2.54390000
H	-3.36330100	-2.31925100	2.67270500
H	-1.73002800	-2.99931900	2.54353000
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C	-2.30615000	-2.07114500	-2.54346700
H	-1.73001400	-2.99988300	-2.54288700
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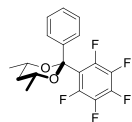
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H	-0.01734700	-2.38601900	1.28485200
H	-0.01743800	-2.38605900	-1.28478000
H	-2.75619000	-2.82909100	0.00014000
H	-1.39573900	-3.96530900	0.00010900
O	-1.35673900	-0.80851600	-1.17376900
O	-1.35665800	-0.80848000	1.17388700
C	0.65181600	-0.05879500	-0.00002200
C	1.36046700	0.03098100	1.20053800
C	1.36038500	0.03093800	-1.20063300
C	2.74403800	0.19145900	1.20964500
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C	2.74395600	0.19141500	-1.20984100
H	0.82651600	-0.02434200	-2.14221100
C	3.42566000	0.26877800	-0.00012200
H	3.28632000	0.25726400	2.14555900
H	3.28617400	0.25718600	-2.14579400
C	-1.49455400	1.24370200	0.00003200
C	-1.75433000	1.90113400	-1.20474000
C	-1.75425900	1.90116700	1.20480200
C	-2.26598000	3.19730200	-1.20368900
H	-1.57306200	1.39195100	-2.14301400
C	-2.26590800	3.19733500	1.20374600
H	-1.57293600	1.39200900	2.14307900
C	-2.52150200	3.85144600	0.00002700
H	-2.46947400	3.69433300	-2.14709900
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H	-2.80976400	-2.53683200	-2.53882500
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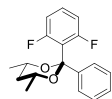
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C	-2.79157700	-2.11504400	0.00021000
H	-2.97236900	-0.40060200	-1.28677900
H	-2.97239000	-0.40032200	1.28682500
H	-2.28929500	-3.08895200	0.00032000
H	-3.87263500	-2.29260400	0.00022200
O	-0.99245900	-0.99940700	1.17336800
O	-0.99244200	-0.99966400	-1.17316400
C	-1.11372400	1.14482700	-0.00013400
C	-1.31505500	1.82753800	-1.20303600
C	-1.31507800	1.82780200	1.20261300
C	-1.72155200	3.16060900	-1.20414000
H	-1.15208200	1.31195200	-2.14264900
C	-1.72157500	3.16087300	1.20341700
H	-1.15212300	1.31242300	2.14234300
C	-1.92754100	3.83238300	-0.00043700
H	-1.87547500	3.67503600	-2.14758800
H	-1.87551600	3.67550700	2.14674900
C	0.93851500	-0.30260000	0.00004000
C	1.64721900	-0.27975800	1.20256700
C	1.64723900	-0.28004400	-1.20248000
C	3.03923900	-0.23334100	1.20981700
H	1.11177600	-0.31527500	2.14272400
C	3.03926000	-0.23362800	-1.20971700
H	1.11181200	-0.31578400	-2.14263700
C	3.72391200	-0.20782600	0.00005300
H	3.58546500	-0.22210300	2.14561800
H	3.58550100	-0.22261200	-2.14551100
C	-2.58693400	-2.10280100	2.54293900
H	-3.63975500	-2.36846100	2.67309800
H	-1.99628000	-3.02233400	2.53816800
H	-2.27798400	-1.50324400	3.40240300
C	-2.58689800	-2.10335300	-2.54251900
H	-1.99624600	-3.02288600	-2.53754000
H	-3.63971800	-2.36904000	-2.67263500
H	-2.27793500	-1.50398300	-3.40210800
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Cl	5.48432300	-0.14898500	0.00006000



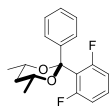
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C	-1.82434600	-2.90980700	0.00010000
H	-0.19208300	-2.37767200	1.30033500
H	-0.19216900	-2.37770600	-1.30025900
H	-2.91836100	-2.85435100	0.00013500
H	-1.54058000	-3.96775700	0.00010400
O	-1.53478300	-0.80610900	-1.16034100
O	-1.53470500	-0.80607800	1.16046400
C	0.51152400	-0.08975500	-0.00001600
C	1.25406600	0.01412100	1.18269100
C	1.25398800	0.01408800	-1.18277500
C	2.63601400	0.17003500	1.19421400
C	2.63593500	0.17000200	-1.19439400
C	3.33596600	0.24642300	-0.00011400
C	-1.60251000	1.25900800	0.00003600
C	-1.83441000	1.92234800	-1.20754900
C	-1.83432800	1.92238100	1.20761900
C	-2.29660100	3.23690300	-1.20465200
H	-1.66764400	1.40578800	-2.14404400
C	-2.29651900	3.23693600	1.20471900
H	-1.66749800	1.40584600	2.14411700
C	-2.52728500	3.89878500	0.00003200
H	-2.48080300	3.74208100	-2.14748200
H	-2.48065800	3.74213900	2.14754700
H	-2.88814800	4.92240200	0.00003100
C	-1.91408700	-2.69685900	-2.54325200
H	-1.73452100	-3.76637700	-2.68358500
H	-2.99345900	-2.52658700	-2.52832800
H	-1.49323000	-2.16271300	-3.39734800
C	-1.91391700	-2.69679000	2.54345200
H	-2.99329100	-2.52651900	2.52859400
H	-1.73434300	-3.76630500	2.68380100
H	-1.49300400	-2.16262200	3.39750600
F	4.66156900	0.39496000	-0.00016000
F	0.66652100	-0.02328100	2.38904000
F	3.29363500	0.25130100	2.35619100
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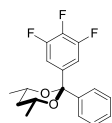
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C	-2.91318900	-2.16452600	0.00493800
H	-3.13630900	-0.45531000	-1.28131000
H	-3.13641100	-0.44932500	1.28318000
H	-2.38637900	-3.12521800	0.00720200
H	-3.98926600	-2.36938100	0.00536600
O	-1.14120000	-0.99287600	1.16591100
O	-1.14110400	-0.99826600	-1.16130900
C	-1.31895200	1.15675000	-0.00266400
C	-1.53477300	1.82801700	-1.20986600
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H	-1.35375700	1.31398000	-2.14648600
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H	-1.35379500	1.32382900	2.14041300
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H	-2.14318900	3.65883500	-2.15597200
H	-2.14321400	3.66870200	2.13912300
C	0.77380300	-0.23303600	0.00058000
C	1.51671800	-0.17691400	1.18711400
C	1.51670300	-0.18278600	-1.18622200
C	2.90741600	-0.14343100	1.19423800
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C	3.61111600	-0.13797500	0.00032500
C	-2.69675800	-2.13132200	2.54877700
H	-3.74179800	-2.42199100	2.68771500
H	-2.08375400	-3.03603400	2.54597000
H	-2.39493100	-1.51818600	3.40057900
C	-2.69650600	-2.14317700	-2.53901200
H	-2.08347900	-3.04784800	-2.53193700
H	-3.74152500	-2.43451500	-2.67669700
H	-2.39461400	-1.53400500	-3.39363100
H	-2.54339600	4.84662000	-0.01114600
F	4.94537800	-0.10531400	0.00023500
F	3.56992400	-0.10480100	2.35627800
F	0.93411400	-0.12059500	2.39190500
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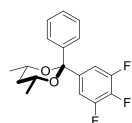
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C	2.35104800	-2.05592100	0.00009300
H	2.32170400	-0.34096000	1.30217900
H	2.32171500	-0.34106600	-1.30213200
H	1.97791900	-3.08603500	0.00013400
H	3.44600500	-2.09398300	0.00009800
O	0.42573400	-1.16081200	-1.15919600
O	0.42572700	-1.16072100	1.15929600
C	0.36835100	1.01033200	-0.00003800
C	0.50120300	1.76574300	1.17429800
C	0.50116300	1.76566100	-1.17443000
C	0.78193600	3.12395000	1.20065600
C	0.78189500	3.12386600	-1.20089300
C	0.92787700	3.80750700	-0.00014500
H	0.87222900	3.62008500	2.15964100
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C	-1.56063800	-0.59284900	0.00001700
C	-2.26350000	-0.61578600	-1.20711900
C	-2.26351800	-0.61573600	1.20714200
C	-3.65615600	-0.66465700	-1.20449100
H	-1.71923700	-0.60831900	-2.14273500
C	-3.65617500	-0.66460600	1.20449400
H	-1.71927100	-0.60823000	2.14276700
C	-4.35718000	-0.68781400	-0.00000300
H	-4.19337900	-0.68944200	-2.14750200
H	-4.19341200	-0.68935200	2.14749800
H	-5.44199500	-0.72719000	-0.00001100
C	2.11799200	-2.08269500	-2.54241500
H	3.19277300	-2.22885700	-2.68293200
H	1.63511500	-3.06308100	-2.52567900
H	1.73192400	-1.52385300	-3.39726700
C	2.11797700	-2.08248800	2.54260300
H	1.63510200	-3.06287600	2.52594400
H	3.19275600	-2.22863500	2.68314100
H	1.73190000	-1.52357800	3.39740600
H	1.14493700	4.86965600	-0.00018500
F	0.34544300	1.17153300	2.38022800
F	0.34536200	1.17136600	-2.38031400



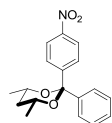
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C	-2.00334400	-1.26643200	1.24500000
C	-2.43602200	-2.03699600	0.00081200
H	-2.54956600	-0.31507800	-1.28141800
H	-2.54977500	-0.31381500	1.28133300
H	-1.97163000	-3.02951200	0.00133900
H	-3.52327800	-2.17217400	0.00078200
O	-0.59356700	-0.98318600	1.16403400
O	-0.59336500	-0.98429600	-1.16310500
C	-0.64437500	1.17479500	-0.00056200
C	-0.82195800	1.86003600	-1.20605500
C	-0.82262100	1.86100900	1.20427700
C	-1.18912300	3.20452100	-1.20605400
H	-0.66582500	1.33799700	-2.14265300
C	-1.18978700	3.20549200	1.20299100
H	-0.66701800	1.33972200	2.14138400
C	-1.37692200	3.88126000	-0.00185600
H	-1.32652400	3.72390100	-2.14936600
H	-1.32771100	3.72563100	2.14580900
C	1.36705300	-0.32934000	0.00026400
C	2.12818200	-0.31611800	1.17869600
C	2.12816900	-0.31796500	-1.17818400
C	3.51425600	-0.37227000	1.20101000
C	3.51424100	-0.37416200	-1.20043600
C	4.21149900	-0.41346900	0.00031400
H	4.01930600	-0.37241700	2.15953100
H	4.01927500	-0.37583000	-2.15896500
C	-2.21704200	-2.02247400	2.54397300
H	-3.27842400	-2.24705900	2.68281400
H	-1.66182300	-2.96383400	2.53854300
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H	-3.27792300	-2.24971000	-2.68113600
H	-1.87545400	-1.43496500	-3.39572700
H	-1.66301800	4.92827200	-0.00235700
F	1.52375500	-0.21383500	2.38223600
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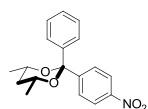
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C	-1.08448800	3.57664800	-0.00011000
H	0.38786700	2.69148800	-1.32244200
H	0.38779100	2.69154500	1.32234500
H	-2.16077800	3.77181700	-0.00014500
H	-0.56420400	4.54033900	-0.00011600
O	-1.28766100	1.46090000	1.17553800
O	-1.28759300	1.46084800	-1.17567700
C	0.47376300	0.24746900	0.00000800
C	1.12871800	-0.00784700	-1.20641700
C	1.12865300	-0.00778200	1.20648200
C	2.42112200	-0.50396600	-1.19310200
C	2.42105800	-0.50390100	1.19326400
C	3.08690600	-0.75855400	0.00010600
C	-1.92427700	-0.49529400	-0.00004500
C	-2.33468600	-1.06937500	1.20539200
C	-2.33461700	-1.06942800	-1.20548000
C	-3.14450900	-2.20329900	1.20397300
H	-2.03690500	-0.61903300	2.14402100
C	-3.14444000	-2.20335200	-1.20405700
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C	-3.55019300	-2.77583800	-0.00004100
H	-3.46231700	-2.63628100	2.14718200
H	-3.46219400	-2.63637500	-2.14726600
H	-4.18089500	-3.65907200	-0.00004000
F	3.06437600	-0.74828800	-2.34938500
F	4.33791800	-1.23424200	0.00015300
F	3.06424800	-0.74816000	2.34959500
H	0.64322700	0.17133600	-2.15732800
H	0.64311000	0.17145400	2.15735700
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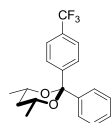
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C	-2.83806300	-2.13069900	0.00001800
H	-3.03912200	-0.41841400	-1.28771400
H	-3.03912200	-0.41839300	1.28772200
H	-2.32468100	-3.09871000	0.00002600
H	-3.91679400	-2.32103800	0.00002000
O	-1.05204600	-0.99327200	1.17305100
O	-1.05204700	-0.99329100	-1.17303400
C	-1.19425100	1.15050800	-0.00001000
C	-1.40044900	1.83106000	-1.20326300
C	-1.40045100	1.83107900	1.20323200
C	-1.81703200	3.16098200	-1.20401800
H	-1.23478700	1.31705600	-2.14326100
C	-1.81703400	3.16100200	1.20396400
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H	-1.97494500	3.67430400	-2.14727000
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C	2.94920800	-0.19106500	1.19281600
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C	3.66110700	-0.15747200	0.00000100
C	-2.63302200	-2.11694500	2.54317900
H	-3.68248200	-2.39498700	2.67377800
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H	-2.03179800	-3.02956300	-2.53775900
H	-3.68248300	-2.39503000	-2.67373700
H	-2.33102600	-1.51415200	-3.40269700
H	-2.35053300	4.86678500	-0.00004100
H	1.05066600	-0.29645600	2.15720900
H	1.05066600	-0.29650800	-2.15720400
F	3.63756300	-0.16963200	-2.35011700
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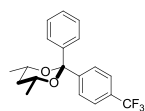
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C	-1.98854000	-2.84766900	0.00009500
H	-0.32100700	-2.40501100	1.28447200
H	-0.32108100	-2.40504300	-1.28438800
H	-3.07726700	-2.72518700	0.00012500
H	-1.76928400	-3.92083600	0.00010300
O	-1.58907200	-0.76832900	-1.17390500
O	-1.58900300	-0.76829900	1.17401900
C	0.44551500	-0.09711200	-0.00001200
C	1.15331100	-0.03520100	1.20512900
C	1.15323800	-0.03522300	-1.20519700
C	2.53876100	0.07435000	1.21469300
H	0.61349200	-0.07229600	2.14345000
C	2.53868700	0.07432800	-1.21484800
H	0.61336100	-0.07233400	-2.14348500
C	3.21495000	0.12564300	-0.00009800
H	3.09487900	0.12044700	2.14160900
H	3.09474900	0.12040900	-2.14179800
C	-1.63707300	1.28970100	0.00003300
C	-1.86484700	1.95787500	-1.20539500
C	-1.86475200	1.95791200	1.20545700
C	-2.31535200	3.27641500	-1.20400100
H	-1.70874800	1.44071300	-2.14380100
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H	-1.70857900	1.44077900	2.14386700
C	-2.53953400	3.94137500	0.00002700
H	-2.49555100	3.78255800	-2.14713500
H	-2.49538100	3.78262400	2.14719100
H	-2.89012300	4.96848700	0.00002500
C	-2.04640900	-2.65350500	-2.54313800
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H	-3.11646000	-2.43192800	-2.53968000
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H	-3.11631300	-2.43186200	2.53992600
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H	-1.59626900	-2.15012000	3.40216400
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O	5.25538400	0.28102600	-1.08484400



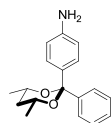
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H	-3.18290100	-0.41180800	-1.28161100
H	-3.18291700	-0.41154600	1.28170300
H	-2.48052500	-3.09783500	0.00032300
H	-4.07011700	-2.31457800	0.00024400
O	-1.19939300	-0.99925600	1.17304500
O	-1.19938500	-0.99952300	-1.17283400
C	-1.32534100	1.14648700	-0.00013000
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C	-1.52726200	1.82841700	1.20313400
C	-1.93607400	3.16034500	-1.20437800
H	-1.36537700	1.31295000	-2.14346900
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H	-1.36559400	1.31336800	2.14317300
C	-2.14300500	3.83139300	-0.00043400
H	-2.09121400	3.67451400	-2.14762400
H	-2.09143700	3.67493500	2.14679000
C	0.72595900	-0.29448500	0.00006000
C	1.43073700	-0.27004200	1.20716700
C	1.43075600	-0.27034100	-1.20705200
C	2.81937800	-0.21800100	1.21482700
H	0.89106700	-0.30928300	2.14403900
C	2.81938600	-0.21838300	-1.21472800
H	0.89109100	-0.30977000	-2.14391900
C	3.49669100	-0.18992200	0.00004600
H	3.37709100	-0.20375600	2.14171900
H	3.37713300	-0.20449200	-2.14161200
C	-2.79077800	-2.10793800	2.54437000
H	-3.84236100	-2.37851600	2.67338100
H	-2.19576300	-3.02461800	2.54419700
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C	-2.79079200	-2.10846100	-2.54393300
H	-2.19582100	-3.02517000	-2.54356600
H	-3.84238700	-2.37901600	-2.67290200
H	-2.48714100	-1.50454300	-3.40217200
H	-2.45989900	4.86924000	-0.00055200
N	4.97122700	-0.13399000	0.00004400
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O	5.54208700	-0.11070100	1.08449900



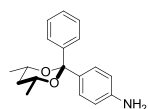
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C	-2.27398000	-2.85546300	0.00021500
H	-0.61023100	-2.40013100	1.28503000
H	-0.61035500	-2.40023000	-1.28479600
H	-3.36371900	-2.74147400	0.00026300
H	-2.04620700	-3.92695700	0.00024400
O	-1.89018700	-0.77344200	-1.17365500
O	-1.89007600	-0.77335300	1.17388900
C	0.14317800	-0.09516500	-0.00000500
C	0.85247400	-0.03103200	1.20213600
C	0.85236200	-0.03113200	-1.20221600
C	2.23915900	0.07966800	1.20679600
H	0.31438100	-0.06514200	2.14193300
C	2.23904700	0.07956700	-1.20701500
H	0.31418200	-0.06532100	-2.14196000
C	2.93652300	0.13447500	-0.00014400
H	2.77506800	0.13059700	2.14750700
H	2.77486800	0.13041600	-2.14778000
C	-1.95054400	1.28348300	0.00004200
C	-2.18399500	1.95013700	-1.20505300
C	-2.18389200	1.95022500	1.20510700
C	-2.64463200	3.26525000	-1.20386400
H	-2.02331600	1.43417800	-2.14336100
C	-2.64452900	3.26533800	1.20386100
H	-2.02313400	1.43433500	2.14343900
C	-2.87410400	3.92871200	-0.00001600
H	-2.82858300	3.76991900	-2.14715200
H	-2.82840000	3.77007600	2.14712800
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C	4.43788600	0.19390900	-0.00021300
F	4.99343500	-1.04781300	-0.00013100
F	4.92831600	0.83008900	-1.08843500
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H	-2.19664300	-3.73835600	-2.67283600
H	-3.40617000	-2.44757500	-2.53878800
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C	-2.33423500	-2.66119200	2.54318200
H	-3.40592500	-2.44738400	2.53929600
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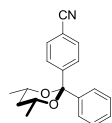
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C	-3.28128700	-2.15561100	0.00007800
H	-3.49651400	-0.44477600	-1.28665200
H	-3.49647100	-0.44474900	1.28678000
H	-2.75960100	-3.11921800	0.00007900
H	-4.35845800	-2.35498300	0.00009900
O	-1.50485300	-1.00345800	1.17305100
O	-1.50489300	-1.00348300	-1.17297900
C	-1.66487300	1.13915100	0.00001600
C	-1.87764500	1.81793800	-1.20310000
C	-1.87760700	1.81796300	1.20312400
C	-2.30756900	3.14360500	-1.20392700
H	-1.70644700	1.30522800	-2.14280100
C	-2.30753100	3.14363000	1.20393600
H	-1.70637900	1.30527300	2.14283000
C	-2.52511400	3.81130000	0.00000100
H	-2.47059600	3.65543700	-2.14718200
H	-2.47052800	3.65548200	2.14718600
C	0.41139200	-0.26994300	-0.00000400
C	1.11747100	-0.23312900	1.20410000
C	1.11743100	-0.23316200	-1.20413400
C	2.50644200	-0.15871300	1.20685100
H	0.58031700	-0.27689100	2.14255000
C	2.50640200	-0.15874700	-1.20693300
H	0.58024600	-0.27695100	-2.14256400
C	3.20442100	-0.11639400	-0.00005300
H	3.04390900	-0.13060300	2.14757000
H	3.04383800	-0.13066300	-2.14767000
H	-2.85828200	4.84410900	-0.00000400
C	4.70620500	-0.08918100	-0.00007800
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C	-3.07676200	-2.13919000	2.54300700
H	-4.12397300	-2.42588300	2.67333700
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H	-4.12406500	-2.42593900	-2.67314700
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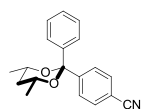
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C	0.78509400	3.08851500	0.00016200
H	-0.72235400	2.25222800	1.28595200
H	-0.72227900	2.25234200	-1.28579000
H	1.87101200	3.23652900	0.00020000
H	0.30934600	4.07558800	0.00019200
O	0.90484100	0.97575800	-1.17347500
O	0.90477200	0.97565200	1.17361700
C	-0.92423000	-0.14415200	-0.00003400
C	-1.60979500	-0.37267000	1.19598100
C	-1.60972000	-0.37257000	-1.19611200
C	-2.93375800	-0.79649000	1.20208200
H	-1.10006000	-0.21835600	2.14054400
C	-2.93368200	-0.79638900	-1.20233100
H	-1.09992600	-0.21817800	-2.14063000
C	-3.62059300	-1.01639800	-0.00015500
H	-3.44307900	-0.95646900	2.14883300
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C	1.43800800	-1.00946400	-0.00000200
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C	2.57849900	-2.77472600	-1.20349000
H	1.54468800	-1.13980800	-2.14224100
C	2.57841300	-2.77484200	1.20339800
H	1.54453400	-1.14001400	2.14223200
C	2.95751700	-3.36673100	-0.00006100
H	2.87580900	-3.22181400	-2.14719800
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H	3.54689700	-4.27834200	-0.00008400
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H	-5.29018700	-1.85459300	0.83488500
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H	0.50547700	3.92884400	-2.67238800
H	1.98499100	2.95897300	-2.53733500
H	0.58016900	2.31682400	-3.40185500
C	0.89276200	2.91411200	2.54253200
H	1.98484500	2.95874500	2.53771600
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H	0.57997200	2.31651900	3.40209800



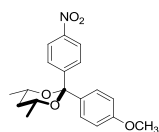
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C	2.52197300	-2.08454900	-0.00003900
H	2.67477700	-0.36752100	1.28627600
H	2.67472100	-0.36754100	-1.28638800
H	2.03539000	-3.06653500	-0.00002100
H	3.60601000	-2.24422400	-0.00006200
O	0.70504500	-1.00002300	-1.17384500
O	0.70509600	-1.00000500	1.17382900
C	0.80034100	1.14421600	-0.00002600
C	0.99520300	1.83016400	1.20227800
C	0.99515500	1.83014600	-1.20234900
C	1.38763900	3.16745100	1.20343200
H	0.83609900	1.31316700	2.14181300
C	1.38759100	3.16743300	-1.20354000
H	0.83601400	1.31313400	-2.14186900
C	1.58685500	3.84176400	-0.00006300
H	1.53582300	3.68347400	2.14710500
H	1.53573700	3.68344100	-2.14722700
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C	-3.34379700	-0.27979000	-1.20198300
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C	-3.34374500	-0.27977800	1.20213300
H	-1.42187300	-0.33911300	2.14110200
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H	-3.87785300	-0.26929000	-2.14860900
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C	2.31775000	-2.07582300	-2.54244800
H	3.37504600	-2.32387400	-2.67225600
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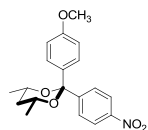
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H	0.10783400	-2.38329000	1.28434100
H	0.10771700	-2.38339300	-1.28416600
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C	0.75735300	-0.04176600	-0.00003200
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C	2.84066600	0.23031200	1.21069600
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H	0.92566800	-0.00780400	-2.14249000
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H	-1.41830600	-3.78910600	-2.67289200
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H	1.21523200	-0.32969400	-2.14296000
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H	1.68688400	2.45913300	-1.15716200
H	1.57136300	2.34624000	1.40750300
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C	0.93700100	0.07905500	-0.00547500
C	1.54106000	-0.32207400	-1.20209900
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H	1.16654100	0.06113300	-2.14345000
C	2.49500700	-1.31731500	1.22396000
H	0.95657300	-0.13604400	2.13379700
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C	-2.20836500	-0.31063700	1.02849600
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H	-6.42431500	-3.41292800	0.24946500
H	-4.96309100	-3.42961200	1.26698100
H	-6.02181300	-1.98871500	1.23956400
C	0.47306100	3.70805800	-2.41774500
H	-0.52980400	4.14154200	-2.44003300
H	1.20290000	4.51998200	-2.47965300
H	0.59103200	3.07577100	-3.30076900
C	0.24596300	3.48636000	2.65865000
H	0.96469500	4.28650400	2.85580200
H	-0.75623100	3.92103000	2.62908300
H	0.28692400	2.77915100	3.49033200

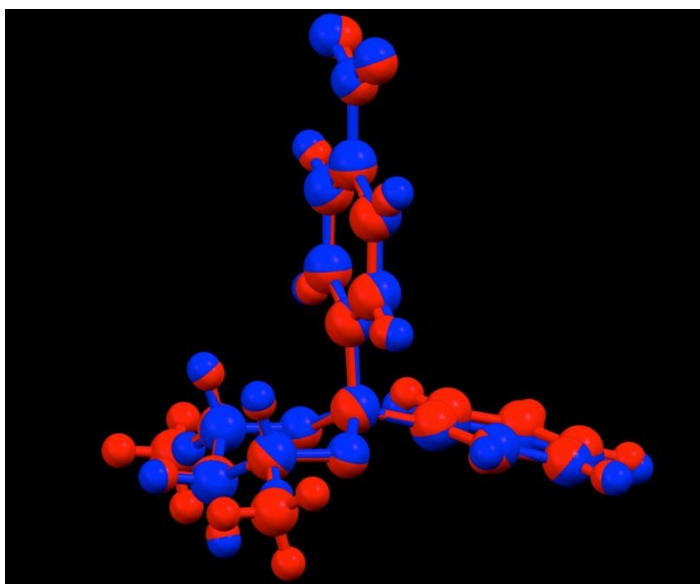


C	1.55108900	2.62495700	-1.16469300
C	0.26012500	0.95118100	0.00886000
C	1.63129100	2.44554000	1.32670300
C	1.69471700	3.40471600	0.14026100
H	2.41505000	1.95587000	-1.27835000
H	2.49916900	1.77306300	1.28851700
H	0.88726000	4.14128200	0.21900100
H	2.64699900	3.94608200	0.14889300
O	0.43226000	1.65014600	1.23165100
O	0.35506800	1.82172500	-1.10715500
C	1.24618300	-0.22698400	-0.11085900
C	1.62728000	-0.71935200	-1.36611800
C	1.71373700	-0.88830100	1.02265000
C	2.45941100	-1.82209500	-1.48108600
H	1.26823300	-0.22986600	-2.26434600
C	2.55184500	-2.00050300	0.92517400
H	1.42402900	-0.53457900	2.00577500
C	2.92996900	-2.47332600	-0.33396800
H	2.75701100	-2.20058600	-2.45278200
H	2.89552400	-2.48286100	1.83159500
C	-1.17383300	0.41602700	0.01662000
C	-1.78737500	0.06020000	1.22167100
C	-1.86842000	0.24064400	-1.18409000
C	-3.07226800	-0.46843100	1.23319400
H	-1.26292900	0.21344300	2.15551700
C	-3.15393300	-0.28711300	-1.18808600
H	-1.40716500	0.53372900	-2.11782400
C	-3.73916900	-0.63895200	0.02403300
H	-3.55977100	-0.74291100	2.15912800
H	-3.70345800	-0.42330000	-2.10994500
N	-5.10315500	-1.20042800	0.02815300
O	-5.59372800	-1.50267600	1.11035300
O	-5.66967700	-1.33425900	-1.05075300
O	3.74164300	-3.54668800	-0.54899700
C	4.23410100	-4.26488400	0.57288100
H	4.84142600	-5.07116900	0.16606800
H	4.85700100	-3.63037000	1.21201100
H	3.41716200	-4.69045600	1.16465600
C	1.58653800	3.14084100	2.67538100
H	2.48550600	3.74615700	2.82117700
H	0.71428100	3.79560800	2.74466100
H	1.53149800	2.41189700	3.48730200
C	1.42582400	3.50545500	-2.39481200
H	0.55555400	4.16160400	-2.31430400
H	2.31803200	4.12713600	-2.50992000
H	1.31447900	2.89952500	-3.29699300

X-Ray Crystallographic Data

Atoms used to map and model positional deviations in the crystallographic and computation structure of **1**

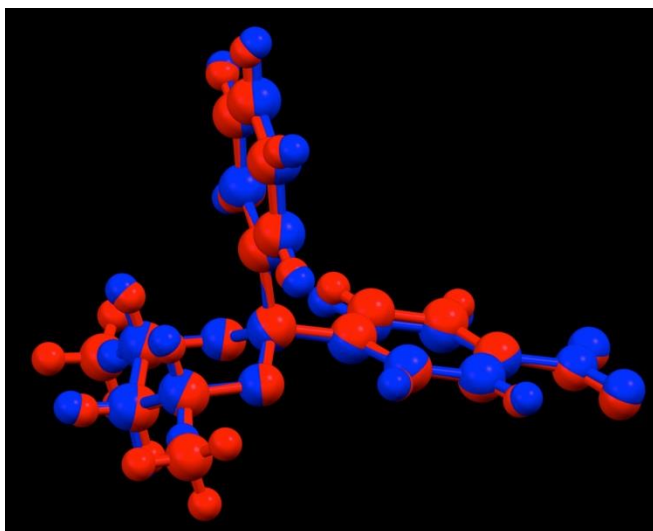
Atom label from crystal data	Atom label from computational data	R.M.S.D. (Å)
O1	O1	0.044
C2	C2	0.030
O3	O3	0.040
C4	C4	0.036
C5	C5	0.029
C6	C6	0.018
C9	C9	0.057
C10	C10	0.047
C11	C11	0.059
C12	C12	0.058
C13	C13	0.070
C14	C14	0.087
C15	C15	0.042
C16	C16	0.156
C17	C17	0.190
C18	C18	0.119
C19	C19	0.038
C20	C20	0.023
N21	N21	0.097
O22	O22	0.066
O23	O23	0.171



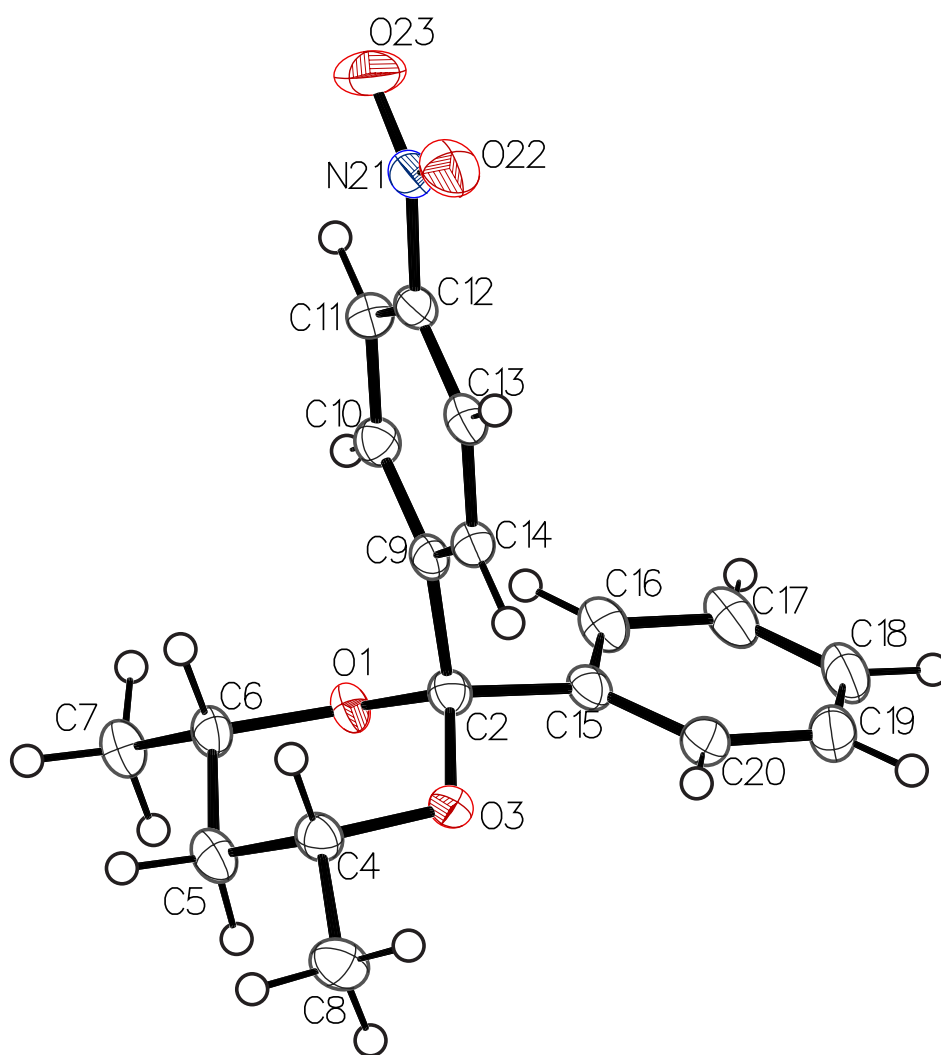
A ball and stick plot of the crystallographic coordinates (shown in red) and computational coordinates (shown in blue) of compound **1**. The root mean square deviation between the mapped atoms is 0.0852 Å. The hydrogen atoms have been removed for clarity.

Atoms used to map and model positional deviations in the crystallographic and computation structure of **2**

Atom label from crystal data	Atom label from computational data	R.M.S.D. (Å)
O1	O1	0.069
C2	C2	0.044
O3	O3	0.067
C4	C4	0.058
C5	C5	0.107
C6	C6	0.068
C9	C9	0.079
C10	C10	0.020
C11	C11	0.048
C12	C12	0.027
C13	C13	0.148
C14	C14	0.179
C15	C15	0.022
C16	C16	0.074
C17	C17	0.139
C18	C18	0.118
C19	C19	0.053
C20	C20	0.011
N21	N21	0.077
O22	O22	0.061
O23	O23	0.174



A ball and stick plot of the crystallographic coordinates (shown in red) and computational coordinates (shown in blue) of compound **2**. The root mean square deviation between the mapped atoms is 0.0913 Å. The hydrogen atoms have been removed for clarity.



The full number scheme of compound **1**. All thermal ellipsoids are shown at a probability level of 50%. All hydrogen atoms are shown as spheres

Crystal data and structure refinement for compound **1**.

Identification code	007_13121	
Empirical formula	C ₁₈ H ₁₉ NO ₄	
Formula weight	313.34	
Temperature	93(2) K	
Wavelength	1.54187 Å	
Crystal system	Monoclinic	
Space group	<i>P</i> 2 ₁ / <i>n</i>	
Unit cell dimensions	<i>a</i> = 9.0607(3) Å	$\alpha = 90^\circ$
	<i>b</i> = 12.9754(4) Å	$\beta = 93.395(7)^\circ$
	<i>c</i> = 13.6636(10) Å	$\gamma = 90^\circ$
Volume	1603.56(14) Å ³	
<i>Z</i>	4	
Density (calculated)	1.298 Mg/m ³	
Absorption coefficient	0.753 mm ⁻¹	
<i>F</i> (000)	664	
Crystal color	Colorless	
Crystal size	0.320 x 0.260 x 0.220 mm ³	
Θ range for data collection	4.704 to 66.543°	
Index ranges	-10 ≤ <i>h</i> ≤ 10, -15 ≤ <i>k</i> ≤ 15, -16 ≤ <i>l</i> ≤ 16	
Reflections collected	47214	
Independent reflections	2799 [<i>R</i> (int) = 0.0630]	
Completeness to $\theta = 66.543^\circ$	99.0 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.852 and 0.744	
Refinement method	Full-matrix least-squares on <i>F</i> ²	
Data / restraints / parameters	2799 / 0 / 210	
Goodness-of-fit on <i>F</i> ²	1.088	
Final <i>R</i> indices [<i>I</i> > 2σ(<i>I</i>) = 2404 data]	<i>R</i> 1 = 0.0394, <i>wR</i> 2 = 0.0996	
<i>R</i> indices (all data)	<i>R</i> 1 = 0.0460, <i>wR</i> 2 = 0.1036	
Largest diff. peak and hole	0.173 and -0.250 e.Å ⁻³	

Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for compound **1**. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)
O(1)	2142(1)	5426(1)	3074(1)	20(1)
C(2)	2453(2)	6337(1)	2551(1)	19(1)
O(3)	3766(1)	6818(1)	2935(1)	21(1)
C(4)	3768(2)	7060(1)	3968(1)	23(1)
C(5)	3453(2)	6082(1)	4525(1)	25(1)
C(6)	2035(2)	5581(1)	4118(1)	22(1)
C(7)	1738(2)	4532(1)	4545(1)	26(1)
C(8)	5262(2)	7525(1)	4249(1)	30(1)
C(9)	1134(2)	7080(1)	2510(1)	18(1)
C(10)	-302(2)	6689(1)	2494(1)	22(1)
C(11)	-1510(2)	7338(1)	2366(1)	24(1)
C(12)	-1248(2)	8386(1)	2259(1)	21(1)
C(13)	164(2)	8798(1)	2285(1)	21(1)
C(14)	1358(2)	8136(1)	2407(1)	20(1)
C(15)	2724(2)	6006(1)	1507(1)	21(1)
C(16)	1924(2)	5196(1)	1076(1)	26(1)
C(17)	2147(2)	4903(1)	118(1)	31(1)
C(18)	3165(2)	5424(1)	-415(1)	33(1)
C(19)	3944(2)	6244(1)	2(1)	32(1)
C(20)	3732(2)	6539(1)	964(1)	26(1)
N(21)	-2508(1)	9085(1)	2106(1)	27(1)
O(22)	-2256(1)	10013(1)	2028(1)	36(1)
O(23)	-3762(1)	8722(1)	2054(1)	44(1)

Bond lengths [Å] and angles [°] for compound **1**.

O(1)-C(2)	1.4184(17)
O(1)-C(6)	1.4491(17)
C(2)-O(3)	1.4165(17)
C(2)-C(15)	1.523(2)
C(2)-C(9)	1.5340(19)
O(3)-C(4)	1.4462(17)
C(4)-C(8)	1.510(2)
C(4)-C(5)	1.515(2)
C(4)-H(4)	1.0000
C(5)-C(6)	1.516(2)
C(5)-H(5A)	0.9900
C(5)-H(5B)	0.9900
C(6)-C(7)	1.511(2)
C(6)-H(6)	1.0000
C(7)-H(7A)	0.9800
C(7)-H(7B)	0.9800
C(7)-H(7C)	0.9800
C(8)-H(8A)	0.9800
C(8)-H(8B)	0.9800
C(8)-H(8C)	0.9800
C(9)-C(14)	1.393(2)
C(9)-C(10)	1.396(2)
C(10)-C(11)	1.384(2)
C(10)-H(10)	0.9500
C(11)-C(12)	1.389(2)
C(11)-H(11)	0.9500
C(12)-C(13)	1.385(2)
C(12)-N(21)	1.4634(19)
C(13)-C(14)	1.384(2)
C(13)-H(13)	0.9500
C(14)-H(14)	0.9500
C(15)-C(16)	1.388(2)
C(15)-C(20)	1.394(2)
C(16)-C(17)	1.390(2)
C(16)-H(16)	0.9500
C(17)-C(18)	1.384(3)
C(17)-H(17)	0.9500
C(18)-C(19)	1.381(3)
C(18)-H(18)	0.9500
C(19)-C(20)	1.393(2)
C(19)-H(19)	0.9500
C(20)-H(20)	0.9500
N(21)-O(23)	1.2275(18)
N(21)-O(22)	1.2312(18)
C(2)-O(1)-C(6)	114.03(11)
O(3)-C(2)-O(1)	111.57(11)
O(3)-C(2)-C(15)	107.02(11)
O(1)-C(2)-C(15)	106.53(11)
O(3)-C(2)-C(9)	111.86(11)
O(1)-C(2)-C(9)	111.39(11)
C(15)-C(2)-C(9)	108.16(11)
C(2)-O(3)-C(4)	114.21(10)
O(3)-C(4)-C(8)	106.49(12)

O(3)-C(4)-C(5)	108.59(12)
C(8)-C(4)-C(5)	113.58(13)
O(3)-C(4)-H(4)	109.4
C(8)-C(4)-H(4)	109.4
C(5)-C(4)-H(4)	109.4
C(4)-C(5)-C(6)	110.83(12)
C(4)-C(5)-H(5A)	109.5
C(6)-C(5)-H(5A)	109.5
C(4)-C(5)-H(5B)	109.5
C(6)-C(5)-H(5B)	109.5
H(5A)-C(5)-H(5B)	108.1
O(1)-C(6)-C(7)	106.20(11)
O(1)-C(6)-C(5)	108.40(12)
C(7)-C(6)-C(5)	114.23(13)
O(1)-C(6)-H(6)	109.3
C(7)-C(6)-H(6)	109.3
C(5)-C(6)-H(6)	109.3
C(6)-C(7)-H(7A)	109.5
C(6)-C(7)-H(7B)	109.5
H(7A)-C(7)-H(7B)	109.5
C(6)-C(7)-H(7C)	109.5
H(7A)-C(7)-H(7C)	109.5
H(7B)-C(7)-H(7C)	109.5
C(4)-C(8)-H(8A)	109.5
C(4)-C(8)-H(8B)	109.5
H(8A)-C(8)-H(8B)	109.5
C(4)-C(8)-H(8C)	109.5
H(8A)-C(8)-H(8C)	109.5
H(8B)-C(8)-H(8C)	109.5
C(14)-C(9)-C(10)	119.79(13)
C(14)-C(9)-C(2)	120.27(12)
C(10)-C(9)-C(2)	119.73(12)
C(11)-C(10)-C(9)	120.68(14)
C(11)-C(10)-H(10)	119.7
C(9)-C(10)-H(10)	119.7
C(10)-C(11)-C(12)	118.06(14)
C(10)-C(11)-H(11)	121.0
C(12)-C(11)-H(11)	121.0
C(13)-C(12)-C(11)	122.58(13)
C(13)-C(12)-N(21)	118.40(13)
C(11)-C(12)-N(21)	119.01(13)
C(14)-C(13)-C(12)	118.51(14)
C(14)-C(13)-H(13)	120.7
C(12)-C(13)-H(13)	120.7
C(13)-C(14)-C(9)	120.37(13)
C(13)-C(14)-H(14)	119.8
C(9)-C(14)-H(14)	119.8
C(16)-C(15)-C(20)	119.45(14)
C(16)-C(15)-C(2)	120.12(13)
C(20)-C(15)-C(2)	120.37(13)
C(15)-C(16)-C(17)	120.35(15)
C(15)-C(16)-H(16)	119.8
C(17)-C(16)-H(16)	119.8
C(18)-C(17)-C(16)	120.04(16)
C(18)-C(17)-H(17)	120.0
C(16)-C(17)-H(17)	120.0

C(19)-C(18)-C(17)	119.96(15)
C(19)-C(18)-H(18)	120.0
C(17)-C(18)-H(18)	120.0
C(18)-C(19)-C(20)	120.36(16)
C(18)-C(19)-H(19)	119.8
C(20)-C(19)-H(19)	119.8
C(19)-C(20)-C(15)	119.81(16)
C(19)-C(20)-H(20)	120.1
C(15)-C(20)-H(20)	120.1
O(23)-N(21)-O(22)	123.05(13)
O(23)-N(21)-C(12)	118.83(14)
O(22)-N(21)-C(12)	118.12(13)

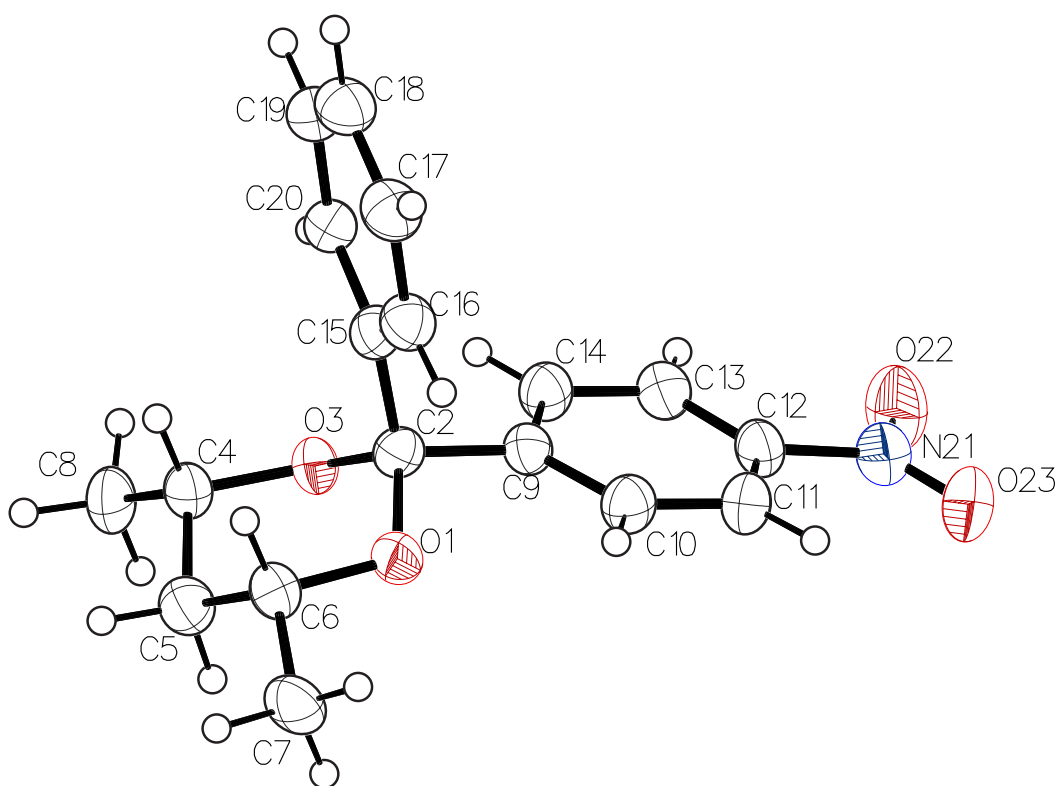
Symmetry transformations used to generate equivalent atoms:

Anisotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for compound **1**. The anisotropic displacement factor exponent takes the form: $-2\pi^2 [h^2 a^{*2} U^{11} + \dots + 2 h k a^* b^* U^{12}]$

	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
O(1)	27(1)	18(1)	15(1)	2(1)	1(1)	2(1)
C(2)	20(1)	18(1)	19(1)	3(1)	1(1)	0(1)
O(3)	18(1)	25(1)	18(1)	-1(1)	-1(1)	0(1)
C(4)	24(1)	25(1)	18(1)	-4(1)	-1(1)	2(1)
C(5)	31(1)	26(1)	17(1)	0(1)	-1(1)	2(1)
C(6)	26(1)	23(1)	15(1)	0(1)	3(1)	2(1)
C(7)	33(1)	26(1)	20(1)	4(1)	1(1)	0(1)
C(8)	28(1)	32(1)	30(1)	-1(1)	-5(1)	-3(1)
C(9)	21(1)	20(1)	13(1)	0(1)	0(1)	1(1)
C(10)	23(1)	21(1)	21(1)	2(1)	1(1)	-1(1)
C(11)	19(1)	30(1)	22(1)	2(1)	1(1)	-1(1)
C(12)	22(1)	26(1)	16(1)	1(1)	0(1)	7(1)
C(13)	27(1)	20(1)	16(1)	2(1)	0(1)	2(1)
C(14)	20(1)	21(1)	18(1)	1(1)	1(1)	0(1)
C(15)	24(1)	21(1)	18(1)	2(1)	0(1)	7(1)
C(16)	32(1)	23(1)	22(1)	2(1)	-1(1)	2(1)
C(17)	44(1)	28(1)	20(1)	-1(1)	-5(1)	9(1)
C(18)	44(1)	37(1)	17(1)	1(1)	2(1)	16(1)
C(19)	33(1)	39(1)	23(1)	6(1)	6(1)	9(1)
C(20)	25(1)	30(1)	23(1)	4(1)	2(1)	5(1)
N(21)	27(1)	36(1)	19(1)	2(1)	2(1)	11(1)
O(22)	42(1)	31(1)	33(1)	2(1)	1(1)	16(1)
O(23)	22(1)	54(1)	55(1)	10(1)	-2(1)	9(1)

Hydrogen coordinates ($\times 10^4$) and isotropic displacement parameters ($\text{\AA}^2 \times 10^{-3}$)
for compound **1**.

	x	y	z	U(eq)
H(4)	2979	7579	4077	27
H(5A)	3366	6247	5227	30
H(5B)	4286	5594	4475	30
H(6)	1182	6048	4228	26
H(7A)	839	4242	4220	39
H(7B)	1607	4600	5249	39
H(7C)	2576	4075	4444	39
H(8A)	6039	7027	4119	45
H(8B)	5318	7700	4948	45
H(8C)	5398	8150	3862	45
H(10)	-452	5970	2571	26
H(11)	-2489	7075	2352	28
H(13)	309	9519	2220	26
H(14)	2335	8402	2420	23
H(16)	1219	4840	1438	31
H(17)	1601	4345	-172	38
H(18)	3328	5217	-1067	40
H(19)	4628	6608	-369	38
H(20)	4271	7103	1248	31



The full number scheme for the crystal structure of compound **2**. All thermal ellipsoids are shown at a probability level of 50%. All hydrogen atoms are shown as spheres

Crystal data and structure refinement for compound **2**.

Identification code	007_13129	
Empirical formula	C ₁₈ H ₁₉ NO ₄	
Formula weight	313.34	
Temperature	93(2) K	
Wavelength	1.54187 Å	
Crystal system	Monoclinic	
Space group	P 21	
Unit cell dimensions	a = 7.7461(2) Å	$\alpha = 90^\circ$
	b = 13.7554(3) Å	$\beta = 106.570(7)^\circ$
	c = 8.0544(6) Å	$\gamma = 90^\circ$
Volume	822.56(7) Å ³	
Z	2	
Density (calculated)	1.265 Mg/m ³	
Absorption coefficient	0.734 mm ⁻¹	
F(000)	332	
Crystal color	Colorless	
Crystal size	0.120 x 0.120 x 0.030 mm ³	
Θ range for data collection	5.731 to 66.554°	
Index ranges	-9 ≤ h ≤ 9, -16 ≤ k ≤ 16, -9 ≤ l ≤ 9	
Reflections collected	28960	
Independent reflections	2859 [R(int) = 0.1060]	
Completeness to $\theta = 66.554^\circ$	98.7 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.978 and 0.709	
Refinement method	Full-matrix least-squares on F ²	
Data / restraints / parameters	2859 / 1 / 211	
Goodness-of-fit on F ²	1.111	
Final R indices [I > 2σ(I) = 2417 data]	R1 = 0.0615, wR2 = 0.1639	
R indices (all data)	R1 = 0.0731, wR2 = 0.1909	
Absolute structure parameter	0.07(13)	
Extinction coefficient	0.014(4)	
Largest diff. peak and hole	0.271 and -0.288 e.Å ⁻³	

Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for compound **2**. $U(\text{eq})$ is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	$U(\text{eq})$
O(1)	3223(4)	4560(2)	659(5)	35(1)
C(2)	4826(6)	3997(3)	1081(6)	31(1)
O(3)	4744(4)	3223(2)	2215(4)	33(1)
C(4)	3213(7)	2588(4)	1554(7)	36(1)
C(5)	1518(7)	3187(4)	1164(7)	40(1)
C(6)	1595(7)	4006(4)	-64(7)	38(1)
C(7)	92(7)	4734(5)	-387(8)	45(1)
C(8)	3344(8)	1802(4)	2888(8)	44(1)
C(9)	6310(6)	4667(3)	2122(6)	33(1)
C(10)	6140(8)	5671(4)	1886(7)	39(1)
C(11)	7481(7)	6282(4)	2861(7)	41(1)
C(12)	8939(7)	5877(4)	4029(7)	38(1)
C(13)	9178(7)	4889(4)	4274(8)	41(1)
C(14)	7822(7)	4276(4)	3283(7)	38(1)
C(15)	5283(7)	3640(3)	-525(7)	34(1)
C(16)	4746(7)	4156(4)	-2068(7)	39(1)
C(17)	5233(8)	3849(4)	-3522(7)	44(1)
C(18)	6303(7)	3036(4)	-3435(7)	43(1)
C(19)	6871(8)	2525(4)	-1908(7)	44(1)
C(20)	6383(7)	2824(4)	-445(7)	35(1)
N(21)	10303(7)	6535(4)	5110(7)	50(1)
O(22)	11594(6)	6181(4)	6208(6)	66(1)
O(23)	10083(7)	7408(3)	4870(7)	63(1)

Bond lengths [Å] and angles [°] for compound **2**.

O(1)-C(2)	1.420(5)
O(1)-C(6)	1.446(6)
C(2)-O(3)	1.416(6)
C(2)-C(15)	1.517(7)
C(2)-C(9)	1.525(7)
O(3)-C(4)	1.447(6)
C(4)-C(5)	1.506(7)
C(4)-C(8)	1.507(7)
C(4)-H(4)	1.0000
C(5)-C(6)	1.512(7)
C(5)-H(5A)	0.9900
C(5)-H(5B)	0.9900
C(6)-C(7)	1.501(8)
C(6)-H(6)	1.0000
C(7)-H(7A)	0.9800
C(7)-H(7B)	0.9800
C(7)-H(7C)	0.9800
C(8)-H(8A)	0.9800
C(8)-H(8B)	0.9800
C(8)-H(8C)	0.9800
C(9)-C(14)	1.382(7)
C(9)-C(10)	1.395(7)
C(10)-C(11)	1.392(8)
C(10)-H(10)	0.9500
C(11)-C(12)	1.366(8)
C(11)-H(11)	0.9500
C(12)-C(13)	1.378(8)
C(12)-N(21)	1.473(7)
C(13)-C(14)	1.404(7)
C(13)-H(13)	0.9500
C(14)-H(14)	0.9500
C(15)-C(16)	1.388(7)
C(15)-C(20)	1.400(7)
C(16)-C(17)	1.395(8)
C(16)-H(16)	0.9500
C(17)-C(18)	1.382(8)
C(17)-H(17)	0.9500
C(18)-C(19)	1.376(8)
C(18)-H(18)	0.9500
C(19)-C(20)	1.398(7)
C(19)-H(19)	0.9500
C(20)-H(20)	0.9500
N(21)-O(23)	1.221(7)
N(21)-O(22)	1.231(7)
C(2)-O(1)-C(6)	114.3(3)
O(3)-C(2)-O(1)	111.5(4)
O(3)-C(2)-C(15)	111.8(4)
O(1)-C(2)-C(15)	111.9(4)
O(3)-C(2)-C(9)	105.4(4)
O(1)-C(2)-C(9)	105.8(4)
C(15)-C(2)-C(9)	110.0(4)
C(2)-O(3)-C(4)	113.5(4)
O(3)-C(4)-C(5)	108.7(4)

O(3)-C(4)-C(8)	106.8(4)
C(5)-C(4)-C(8)	114.7(4)
O(3)-C(4)-H(4)	108.8
C(5)-C(4)-H(4)	108.8
C(8)-C(4)-H(4)	108.8
C(4)-C(5)-C(6)	110.5(4)
C(4)-C(5)-H(5A)	109.6
C(6)-C(5)-H(5A)	109.6
C(4)-C(5)-H(5B)	109.6
C(6)-C(5)-H(5B)	109.6
H(5A)-C(5)-H(5B)	108.1
O(1)-C(6)-C(7)	105.2(4)
O(1)-C(6)-C(5)	108.7(4)
C(7)-C(6)-C(5)	115.9(5)
O(1)-C(6)-H(6)	108.9
C(7)-C(6)-H(6)	108.9
C(5)-C(6)-H(6)	108.9
C(6)-C(7)-H(7A)	109.5
C(6)-C(7)-H(7B)	109.5
H(7A)-C(7)-H(7B)	109.5
C(6)-C(7)-H(7C)	109.5
H(7A)-C(7)-H(7C)	109.5
H(7B)-C(7)-H(7C)	109.5
C(4)-C(8)-H(8A)	109.5
C(4)-C(8)-H(8B)	109.5
H(8A)-C(8)-H(8B)	109.5
C(4)-C(8)-H(8C)	109.5
H(8A)-C(8)-H(8C)	109.5
H(8B)-C(8)-H(8C)	109.5
C(14)-C(9)-C(10)	120.4(5)
C(14)-C(9)-C(2)	119.8(4)
C(10)-C(9)-C(2)	119.7(5)
C(11)-C(10)-C(9)	119.6(5)
C(11)-C(10)-H(10)	120.2
C(9)-C(10)-H(10)	120.2
C(12)-C(11)-C(10)	118.7(5)
C(12)-C(11)-H(11)	120.7
C(10)-C(11)-H(11)	120.7
C(11)-C(12)-C(13)	123.5(5)
C(11)-C(12)-N(21)	118.0(5)
C(13)-C(12)-N(21)	118.5(5)
C(12)-C(13)-C(14)	117.5(5)
C(12)-C(13)-H(13)	121.3
C(14)-C(13)-H(13)	121.3
C(9)-C(14)-C(13)	120.2(5)
C(9)-C(14)-H(14)	119.9
C(13)-C(14)-H(14)	119.9
C(16)-C(15)-C(20)	118.3(5)
C(16)-C(15)-C(2)	121.0(4)
C(20)-C(15)-C(2)	120.5(5)
C(15)-C(16)-C(17)	120.8(5)
C(15)-C(16)-H(16)	119.6
C(17)-C(16)-H(16)	119.6
C(18)-C(17)-C(16)	120.3(6)
C(18)-C(17)-H(17)	119.8
C(16)-C(17)-H(17)	119.8

C(19)-C(18)-C(17)	119.6(5)
C(19)-C(18)-H(18)	120.2
C(17)-C(18)-H(18)	120.2
C(18)-C(19)-C(20)	120.6(5)
C(18)-C(19)-H(19)	119.7
C(20)-C(19)-H(19)	119.7
C(19)-C(20)-C(15)	120.3(5)
C(19)-C(20)-H(20)	119.8
C(15)-C(20)-H(20)	119.8
O(23)-N(21)-O(22)	123.4(5)
O(23)-N(21)-C(12)	117.9(5)
O(22)-N(21)-C(12)	118.7(5)

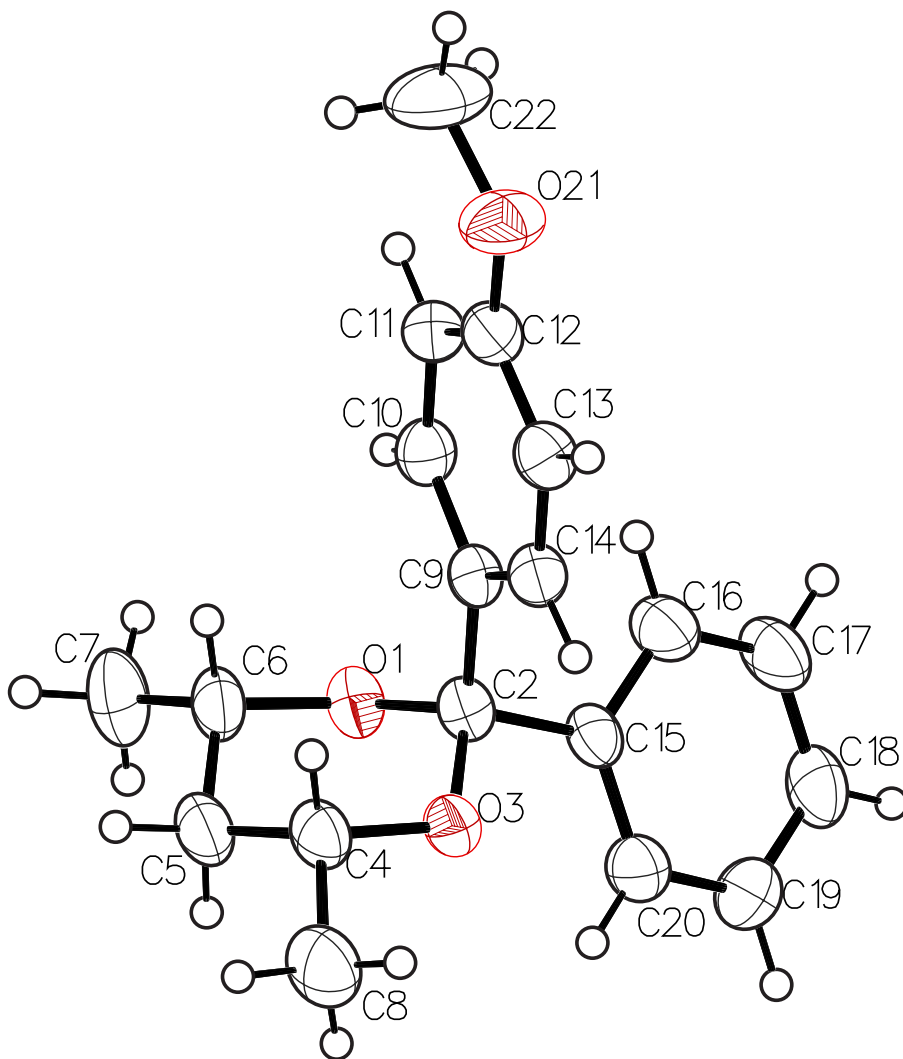
Symmetry transformations used to generate equivalent atoms:

Anisotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for compound **2**. The anisotropic displacement factor exponent takes the form: $-2\pi^2 [h^2 a^{*2} U^{11} + \dots + 2 h k a^* b^* U^{12}]$

	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
O(1)	28(2)	34(2)	44(2)	-1(1)	9(2)	0(1)
C(2)	32(3)	27(2)	33(3)	4(2)	9(2)	4(2)
O(3)	35(2)	30(2)	34(2)	3(1)	10(2)	-6(1)
C(4)	33(3)	36(3)	39(3)	-5(2)	10(2)	-7(2)
C(5)	40(3)	41(3)	41(3)	0(2)	13(2)	-3(2)
C(6)	31(3)	39(3)	42(3)	-3(2)	9(2)	-5(2)
C(7)	28(2)	53(3)	52(3)	1(3)	8(2)	1(2)
C(8)	48(3)	33(3)	53(3)	3(2)	15(3)	-9(2)
C(9)	32(2)	29(2)	37(3)	2(2)	12(2)	-1(2)
C(10)	41(3)	34(3)	41(3)	3(2)	11(2)	0(2)
C(11)	45(3)	31(2)	49(3)	-1(2)	15(3)	-6(2)
C(12)	33(3)	40(3)	41(3)	-6(2)	10(2)	-9(2)
C(13)	39(3)	38(3)	48(3)	0(2)	15(3)	-3(2)
C(14)	37(3)	33(2)	42(3)	3(2)	9(2)	0(2)
C(15)	38(3)	33(2)	33(3)	-2(2)	12(2)	-3(2)
C(16)	40(3)	40(3)	37(3)	0(2)	13(2)	-3(2)
C(17)	45(3)	52(3)	36(3)	0(2)	13(3)	-5(3)
C(18)	43(3)	52(3)	37(3)	-4(2)	15(2)	-4(2)
C(19)	44(3)	42(3)	50(3)	-9(2)	21(3)	-5(2)
C(20)	36(3)	34(2)	37(3)	-1(2)	13(2)	-1(2)
N(21)	46(3)	47(3)	57(3)	-9(2)	18(3)	-10(2)
O(22)	52(3)	66(3)	65(3)	-5(3)	-5(2)	-15(2)
O(23)	61(3)	47(3)	80(3)	-19(2)	19(3)	-20(2)

Hydrogen coordinates ($\times 10^4$) and isotropic displacement parameters ($\text{\AA}^2 \times 10^{-3}$)
for compound **2**.

	x	y	z	U(eq)
H(4)	3304	2282	455	43
H(5A)	1373	3459	2254	48
H(5B)	464	2768	638	48
H(6)	1632	3723	-1198	45
H(7A)	37	5009	719	68
H(7B)	-1052	4412	-958	68
H(7C)	310	5255	-1132	68
H(8A)	3251	2094	3970	67
H(8B)	4504	1468	3101	67
H(8C)	2363	1335	2463	67
H(10)	5114	5936	1063	47
H(11)	7384	6967	2717	49
H(13)	10221	4632	5084	49
H(14)	7945	3591	3410	45
H(16)	4037	4727	-2134	46
H(17)	4827	4200	-4578	53
H(18)	6644	2831	-4423	52
H(19)	7602	1964	-1846	52
H(20)	6799	2471	608	42



The full number scheme of the crystal structure for compound **3**. All thermal ellipsoids are shown at a probability level of 50%. All hydrogen atoms are shown as spheres

Crystal data and structure refinement for compound **3**.

Identification code	mini_13017	
Empirical formula	C ₁₉ H ₂₂ O ₃	
Formula weight	298.36	
Temperature	223(2) K	
Wavelength	0.71075 Å	
Crystal system	Monoclinic	
Space group	<i>P</i> 2 ₁ / <i>n</i>	
Unit cell dimensions	<i>a</i> = 9.3674(10) Å	$\alpha = 90^\circ$
	<i>b</i> = 18.924(2) Å	$\beta = 92.427(7)^\circ$
	<i>c</i> = 9.5002(10) Å	$\gamma = 90^\circ$
Volume	1682.6(3) Å ³	
<i>Z</i>	4	
Density (calculated)	1.178 Mg/m ³	
Absorption coefficient	0.078 mm ⁻¹	
<i>F</i> (000)	640	
Crystal color	Colorless	
Crystal size	0.200 x 0.180 x 0.150 mm ³	
Θ range for data collection	2.991 to 27.476°	
Index ranges	-12 ≤ <i>h</i> ≤ 12, -24 ≤ <i>k</i> ≤ 24, -12 ≤ <i>l</i> ≤ 12	
Reflections collected	26333	
Independent reflections	3855 [<i>R</i> (int) = 0.1071]	
Completeness to $\theta = 25.242^\circ$	99.9 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.988 and 0.707	
Refinement method	Full-matrix least-squares on <i>F</i> ²	
Data / restraints / parameters	3855 / 0 / 202	
Goodness-of-fit on <i>F</i> ²	1.166	
Final <i>R</i> indices [<i>I</i> > 2σ(<i>I</i>) = 2456 data]	<i>R</i> 1 = 0.0877, <i>wR</i> 2 = 0.1433	
<i>R</i> indices (all data)	<i>R</i> 1 = 0.1458, <i>wR</i> 2 = 0.1621	
Largest diff. peak and hole	0.183 and -0.193 e.Å ⁻³	

Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for compound **3**. $U(\text{eq})$ is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)
O(1)	7382(2)	1473(1)	4336(2)	41(1)
C(2)	8700(2)	1814(1)	4757(2)	36(1)
O(3)	9061(2)	1684(1)	6201(2)	38(1)
C(4)	7955(3)	1877(1)	7160(3)	43(1)
C(5)	6570(3)	1505(1)	6716(3)	48(1)
C(6)	6180(3)	1658(1)	5192(3)	44(1)
C(7)	4913(3)	1244(2)	4591(3)	68(1)
C(8)	8520(3)	1677(2)	8617(3)	64(1)
C(9)	8631(2)	2607(1)	4449(2)	33(1)
C(10)	7711(3)	2882(1)	3406(3)	38(1)
C(11)	7637(3)	3603(1)	3130(3)	41(1)
C(12)	8510(3)	4062(1)	3901(3)	41(1)
C(13)	9467(3)	3794(1)	4925(3)	40(1)
C(14)	9530(3)	3079(1)	5190(3)	38(1)
C(15)	9824(2)	1427(1)	3915(2)	36(1)
C(16)	10086(3)	1617(1)	2537(3)	50(1)
C(17)	11038(3)	1235(2)	1757(3)	57(1)
C(18)	11735(3)	658(2)	2328(3)	52(1)
C(19)	11485(3)	464(2)	3691(3)	53(1)
C(20)	10536(3)	847(1)	4483(3)	45(1)
O(21)	8510(2)	4784(1)	3753(2)	60(1)
C(22)	7463(4)	5089(2)	2800(4)	83(1)

Bond lengths [Å] and angles [°] for compound **3**.

O(1)-C(2)	1.436(3)
O(1)-C(6)	1.459(3)
C(2)-O(3)	1.420(3)
C(2)-C(9)	1.531(3)
C(2)-C(15)	1.534(3)
O(3)-C(4)	1.455(3)
C(4)-C(8)	1.509(4)
C(4)-C(5)	1.520(3)
C(4)-H(4)	0.9900
C(5)-C(6)	1.506(4)
C(5)-H(5A)	0.9800
C(5)-H(5B)	0.9800
C(6)-C(7)	1.514(4)
C(6)-H(6)	0.9900
C(7)-H(7A)	0.9700
C(7)-H(7B)	0.9700
C(7)-H(7C)	0.9700
C(8)-H(8A)	0.9700
C(8)-H(8B)	0.9700
C(8)-H(8C)	0.9700
C(9)-C(10)	1.387(3)
C(9)-C(14)	1.397(3)
C(10)-C(11)	1.389(3)
C(10)-H(10)	0.9400
C(11)-C(12)	1.381(3)
C(11)-H(11)	0.9400
C(12)-O(21)	1.374(3)
C(12)-C(13)	1.389(3)
C(13)-C(14)	1.378(3)
C(13)-H(13)	0.9400
C(14)-H(14)	0.9400
C(15)-C(20)	1.382(3)
C(15)-C(16)	1.389(3)
C(16)-C(17)	1.386(4)
C(16)-H(16)	0.9400
C(17)-C(18)	1.372(4)
C(17)-H(17)	0.9400
C(18)-C(19)	1.375(4)
C(18)-H(18)	0.9400
C(19)-C(20)	1.392(4)
C(19)-H(19)	0.9400
C(20)-H(20)	0.9400
O(21)-C(22)	1.428(3)
C(22)-H(22A)	0.9700
C(22)-H(22B)	0.9700
C(22)-H(22C)	0.9700
C(2)-O(1)-C(6)	114.28(18)
O(3)-C(2)-O(1)	110.97(18)
O(3)-C(2)-C(9)	111.16(19)
O(1)-C(2)-C(9)	111.05(19)
O(3)-C(2)-C(15)	106.28(18)
O(1)-C(2)-C(15)	103.97(18)
C(9)-C(2)-C(15)	113.10(18)

C(2)-O(3)-C(4)	114.50(18)
O(3)-C(4)-C(8)	106.3(2)
O(3)-C(4)-C(5)	109.4(2)
C(8)-C(4)-C(5)	113.6(2)
O(3)-C(4)-H(4)	109.1
C(8)-C(4)-H(4)	109.1
C(5)-C(4)-H(4)	109.1
C(6)-C(5)-C(4)	110.3(2)
C(6)-C(5)-H(5A)	109.6
C(4)-C(5)-H(5A)	109.6
C(6)-C(5)-H(5B)	109.6
C(4)-C(5)-H(5B)	109.6
H(5A)-C(5)-H(5B)	108.1
O(1)-C(6)-C(5)	109.1(2)
O(1)-C(6)-C(7)	106.0(2)
C(5)-C(6)-C(7)	114.6(2)
O(1)-C(6)-H(6)	109.0
C(5)-C(6)-H(6)	109.0
C(7)-C(6)-H(6)	109.0
C(6)-C(7)-H(7A)	109.5
C(6)-C(7)-H(7B)	109.5
H(7A)-C(7)-H(7B)	109.5
C(6)-C(7)-H(7C)	109.5
H(7A)-C(7)-H(7C)	109.5
H(7B)-C(7)-H(7C)	109.5
C(4)-C(8)-H(8A)	109.5
C(4)-C(8)-H(8B)	109.5
H(8A)-C(8)-H(8B)	109.5
C(4)-C(8)-H(8C)	109.5
H(8A)-C(8)-H(8C)	109.5
H(8B)-C(8)-H(8C)	109.5
C(10)-C(9)-C(14)	117.6(2)
C(10)-C(9)-C(2)	121.7(2)
C(14)-C(9)-C(2)	120.7(2)
C(9)-C(10)-C(11)	121.8(2)
C(9)-C(10)-H(10)	119.1
C(11)-C(10)-H(10)	119.1
C(12)-C(11)-C(10)	119.5(2)
C(12)-C(11)-H(11)	120.2
C(10)-C(11)-H(11)	120.2
O(21)-C(12)-C(11)	125.0(2)
O(21)-C(12)-C(13)	115.5(2)
C(11)-C(12)-C(13)	119.5(2)
C(14)-C(13)-C(12)	120.5(2)
C(14)-C(13)-H(13)	119.8
C(12)-C(13)-H(13)	119.8
C(13)-C(14)-C(9)	121.0(2)
C(13)-C(14)-H(14)	119.5
C(9)-C(14)-H(14)	119.5
C(20)-C(15)-C(16)	118.1(2)
C(20)-C(15)-C(2)	120.4(2)
C(16)-C(15)-C(2)	121.4(2)
C(17)-C(16)-C(15)	120.8(3)
C(17)-C(16)-H(16)	119.6
C(15)-C(16)-H(16)	119.6
C(18)-C(17)-C(16)	120.6(3)

C(18)-C(17)-H(17)	119.7
C(16)-C(17)-H(17)	119.7
C(17)-C(18)-C(19)	119.2(3)
C(17)-C(18)-H(18)	120.4
C(19)-C(18)-H(18)	120.4
C(18)-C(19)-C(20)	120.5(3)
C(18)-C(19)-H(19)	119.7
C(20)-C(19)-H(19)	119.7
C(15)-C(20)-C(19)	120.7(2)
C(15)-C(20)-H(20)	119.6
C(19)-C(20)-H(20)	119.6
C(12)-O(21)-C(22)	117.6(2)
O(21)-C(22)-H(22A)	109.5
O(21)-C(22)-H(22B)	109.5
H(22A)-C(22)-H(22B)	109.5
O(21)-C(22)-H(22C)	109.5
H(22A)-C(22)-H(22C)	109.5
H(22B)-C(22)-H(22C)	109.5

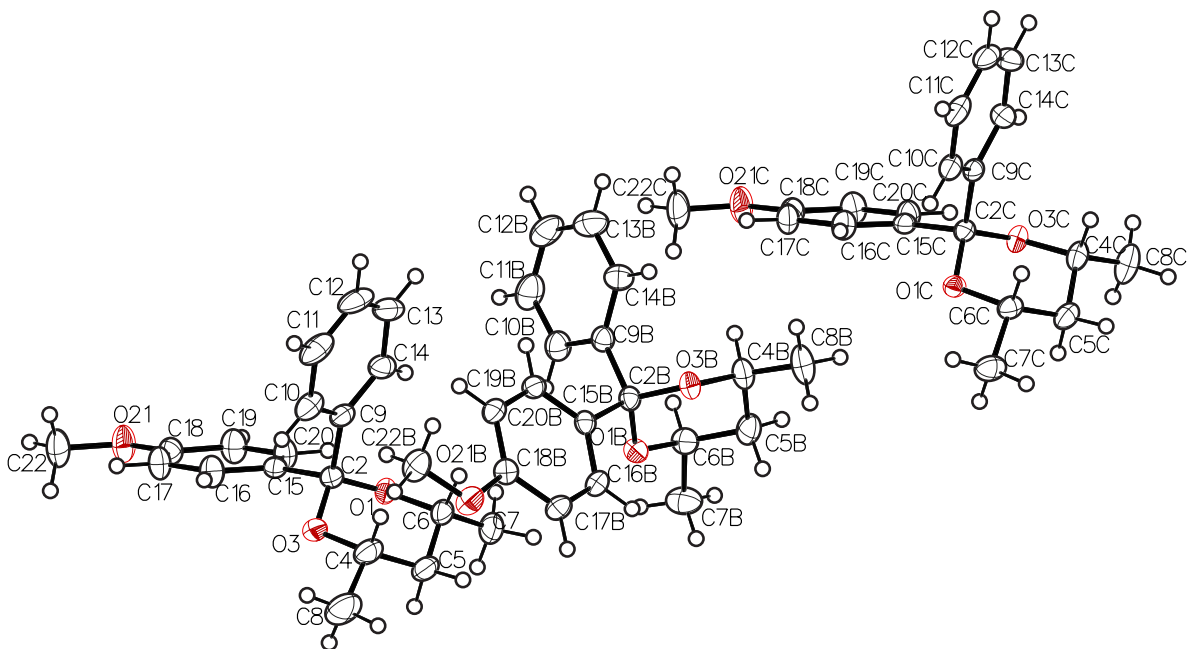
Symmetry transformations used to generate equivalent atoms:

Anisotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for compound **3**. The anisotropic displacement factor exponent takes the form: $-2\pi^2 [h^2 a^{*2} U^{11} + \dots + 2 h k a^* b^* U^{12}]$

	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
O(1)	37(1)	40(1)	45(1)	-6(1)	9(1)	-6(1)
C(2)	34(1)	39(1)	35(1)	-1(1)	4(1)	-5(1)
O(3)	38(1)	42(1)	36(1)	3(1)	9(1)	2(1)
C(4)	44(2)	47(2)	39(2)	-1(1)	13(1)	1(1)
C(5)	44(2)	48(2)	52(2)	3(1)	19(1)	-3(1)
C(6)	34(1)	48(2)	52(2)	-1(1)	15(1)	-1(1)
C(7)	42(2)	88(2)	74(2)	-5(2)	12(2)	-20(2)
C(8)	62(2)	86(2)	44(2)	4(2)	10(2)	-2(2)
C(9)	32(1)	35(1)	33(1)	-3(1)	6(1)	-1(1)
C(10)	34(1)	42(2)	39(1)	-3(1)	0(1)	-4(1)
C(11)	38(1)	46(2)	39(1)	7(1)	1(1)	1(1)
C(12)	41(2)	39(2)	44(2)	4(1)	9(1)	-1(1)
C(13)	39(1)	38(2)	43(2)	-3(1)	1(1)	-7(1)
C(14)	34(1)	41(1)	38(1)	2(1)	4(1)	-1(1)
C(15)	36(1)	31(1)	41(1)	-1(1)	9(1)	-5(1)
C(16)	59(2)	43(2)	49(2)	6(1)	18(1)	7(1)
C(17)	70(2)	54(2)	50(2)	6(1)	29(2)	5(2)
C(18)	50(2)	51(2)	57(2)	-8(2)	23(1)	1(1)
C(19)	49(2)	52(2)	59(2)	4(1)	11(2)	12(1)
C(20)	47(2)	48(2)	42(2)	2(1)	11(1)	5(1)
O(21)	66(1)	36(1)	75(1)	9(1)	-10(1)	0(1)
C(22)	97(3)	46(2)	104(3)	24(2)	-22(2)	5(2)

Hydrogen coordinates ($\times 10^4$) and isotropic displacement parameters ($\text{\AA}^2 \times 10^{-3}$)
for compound **3**.

	x	y	z	U(eq)
H(4)	7804	2394	7119	52
H(5A)	6682	994	6850	57
H(5B)	5802	1667	7306	57
H(6)	5980	2170	5084	53
H(7A)	4765	1353	3598	102
H(7B)	4065	1371	5086	102
H(7C)	5096	742	4704	102
H(8A)	7818	1797	9299	96
H(8B)	9399	1932	8836	96
H(8C)	8706	1173	8652	96
H(10)	7120	2573	2872	46
H(11)	6999	3776	2422	49
H(13)	10075	4104	5439	48
H(14)	10188	2906	5880	45
H(16)	9610	2008	2128	60
H(17)	11209	1373	829	69
H(18)	12375	399	1794	63
H(19)	11959	70	4090	64
H(20)	10378	710	5414	55
H(22A)	7613	4921	1853	125
H(22B)	7549	5599	2826	125
H(22C)	6516	4953	3076	125



The full number scheme of the crystal structure for compound **4**. All thermal ellipsoids are shown at a probability level of 50%. All hydrogen atoms are shown as spheres.

Crystal data and structure refinement for compound **4**.

Identification code	spyder_13104	
Empirical formula	C ₁₉ H ₂₂ O ₃	
Formula weight	298.36	
Temperature	150(2) K	
Wavelength	0.71075 Å	
Crystal system	Triclinic	
Space group	<i>P</i> $\bar{1}$	
Unit cell dimensions	a = 8.2249(3) Å	α = 90.772(6)°
	b = 15.9388(5) Å	β = 100.563(7)°
	c = 19.3071(13) Å	γ = 97.981(7)°
Volume	2462.1(2) Å ³	
Z	6	
Density (calculated)	1.207 Mg/m ³	
Absorption coefficient	0.080 mm ⁻¹	
F(000)	960	
Crystal color	Colorless	
Crystal size	0.400 x 0.300 x 0.300 mm ³	
Θ range for data collection	3.008 to 27.485°	
Index ranges	-10 ≤ h ≤ 10, -20 ≤ k ≤ 20, -25 ≤ l ≤ 25	
Reflections collected	99580	
Independent reflections	11272 [R(int) = 0.0328]	
Completeness to θ = 25.242°	99.8 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.976 and 0.907	
Refinement method	Full-matrix least-squares on F ²	
Data / restraints / parameters	11272 / 0 / 604	
Goodness-of-fit on F ²	1.094	
Final R indices [I > 2 σ (I) = 9411 data]	R1 = 0.0389, wR2 = 0.0947	
R indices (all data)	R1 = 0.0474, wR2 = 0.0999	
Largest diff. peak and hole	0.279 and -0.219 e.Å ⁻³	

Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for compound **4**. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)
O(1)	9375(1)	2774(1)	5594(1)	28(1)
C(2)	8367(1)	2085(1)	5188(1)	24(1)
O(3)	8908(1)	1302(1)	5396(1)	29(1)
C(4)	8972(2)	1154(1)	6138(1)	35(1)
C(5)	10081(2)	1884(1)	6571(1)	36(1)
C(6)	9506(1)	2716(1)	6349(1)	32(1)
C(7)	10714(2)	3483(1)	6668(1)	45(1)
C(8)	9608(2)	316(1)	6272(1)	56(1)
C(9)	6510(1)	2072(1)	5217(1)	26(1)
C(10)	5417(1)	1314(1)	5102(1)	34(1)
C(11)	3720(2)	1310(1)	5091(1)	46(1)
C(12)	3104(2)	2056(1)	5186(1)	51(1)
C(13)	4182(2)	2810(1)	5298(1)	44(1)
C(14)	5886(2)	2821(1)	5318(1)	32(1)
C(15)	8641(1)	2207(1)	4435(1)	24(1)
C(16)	8246(2)	1538(1)	3941(1)	32(1)
C(17)	8502(2)	1636(1)	3252(1)	33(1)
C(18)	9174(1)	2418(1)	3054(1)	28(1)
C(19)	9552(2)	3097(1)	3541(1)	36(1)
C(20)	9287(2)	2992(1)	4222(1)	32(1)
O(21)	9515(1)	2588(1)	2398(1)	40(1)
C(22)	9134(2)	1910(1)	1880(1)	44(1)
O(1B)	8978(1)	4537(1)	7869(1)	26(1)
C(2B)	7218(1)	4319(1)	7791(1)	23(1)
O(3B)	6677(1)	4492(1)	8433(1)	27(1)
C(4B)	7184(2)	5354(1)	8713(1)	32(1)
C(5B)	9053(2)	5580(1)	8789(1)	35(1)
C(6B)	9589(1)	5408(1)	8100(1)	29(1)
C(7B)	11458(2)	5522(1)	8148(1)	42(1)
C(8B)	6578(2)	5399(1)	9404(1)	48(1)
C(9B)	6321(1)	4773(1)	7175(1)	25(1)
C(10B)	7032(2)	4922(1)	6580(1)	33(1)
C(11B)	6186(2)	5291(1)	5999(1)	44(1)
C(12B)	4624(2)	5510(1)	6009(1)	47(1)
C(13B)	3906(2)	5359(1)	6595(1)	43(1)
C(14B)	4745(2)	4989(1)	7176(1)	32(1)
C(15B)	6874(1)	3360(1)	7675(1)	21(1)
C(16B)	7855(1)	2866(1)	8120(1)	25(1)
C(17B)	7594(1)	1994(1)	8041(1)	27(1)
C(18B)	6348(1)	1593(1)	7504(1)	25(1)
C(19B)	5353(1)	2069(1)	7060(1)	25(1)
C(20B)	5623(1)	2950(1)	7152(1)	24(1)
O(21B)	6223(1)	727(1)	7457(1)	35(1)
C(22B)	4950(2)	282(1)	6926(1)	37(1)
O(1C)	6110(1)	7408(1)	10310(1)	23(1)
C(2C)	5466(1)	8145(1)	10044(1)	21(1)
O(3C)	6396(1)	8889(1)	10406(1)	25(1)
C(4C)	6479(1)	8894(1)	11161(1)	29(1)
C(5C)	7209(1)	8120(1)	11447(1)	30(1)
C(6C)	6218(1)	7323(1)	11064(1)	26(1)
C(7C)	7009(2)	6536(1)	11244(1)	36(1)

C(8C)	7518(2)	9721(1)	11452(1)	45(1)
C(9C)	3602(1)	8097(1)	10068(1)	22(1)
C(10C)	2600(1)	7326(1)	10089(1)	27(1)
C(11C)	899(1)	7303(1)	10085(1)	35(1)
C(12C)	192(2)	8041(1)	10051(1)	42(1)
C(13C)	1184(2)	8808(1)	10020(1)	40(1)
C(14C)	2884(2)	8839(1)	10031(1)	31(1)
C(15C)	5725(1)	8187(1)	9282(1)	21(1)
C(16C)	5208(1)	7482(1)	8828(1)	29(1)
C(17C)	5427(2)	7496(1)	8130(1)	31(1)
C(18C)	6190(2)	8232(1)	7883(1)	29(1)
C(19C)	6695(2)	8946(1)	8331(1)	33(1)
C(20C)	6463(2)	8924(1)	9023(1)	28(1)
O(21C)	6490(1)	8322(1)	7212(1)	42(1)
C(22C)	6022(2)	7594(1)	6740(1)	47(1)

Bond lengths [Å] and angles [°] for compound **4**.

O(1)-C(2)	1.4119(13)
O(1)-C(6)	1.4465(13)
C(2)-O(3)	1.4206(13)
C(2)-C(15)	1.5232(14)
C(2)-C(9)	1.5354(14)
O(3)-C(4)	1.4495(13)
C(4)-C(8)	1.5082(19)
C(4)-C(5)	1.5127(18)
C(4)-H(4)	1.0000
C(5)-C(6)	1.5103(18)
C(5)-H(5A)	0.9900
C(5)-H(5B)	0.9900
C(6)-C(7)	1.5096(17)
C(6)-H(6)	1.0000
C(7)-H(7A)	0.9800
C(7)-H(7B)	0.9800
C(7)-H(7C)	0.9800
C(8)-H(8A)	0.9800
C(8)-H(8B)	0.9800
C(8)-H(8C)	0.9800
C(9)-C(14)	1.3885(16)
C(9)-C(10)	1.3905(16)
C(10)-C(11)	1.3909(17)
C(10)-H(10)	0.9500
C(11)-C(12)	1.379(2)
C(11)-H(11)	0.9500
C(12)-C(13)	1.380(2)
C(12)-H(12)	0.9500
C(13)-C(14)	1.3925(17)
C(13)-H(13)	0.9500
C(14)-H(14)	0.9500
C(15)-C(16)	1.3844(15)
C(15)-C(20)	1.3881(16)
C(16)-C(17)	1.3920(16)
C(16)-H(16)	0.9500
C(17)-C(18)	1.3806(16)
C(17)-H(17)	0.9500
C(18)-O(21)	1.3676(13)
C(18)-C(19)	1.3881(16)
C(19)-C(20)	1.3801(16)
C(19)-H(19)	0.9500
C(20)-H(20)	0.9500
O(21)-C(22)	1.4237(15)
C(22)-H(22A)	0.9800
C(22)-H(22B)	0.9800
C(22)-H(22C)	0.9800
O(1B)-C(2B)	1.4206(12)
O(1B)-C(6B)	1.4438(13)
C(2B)-O(3B)	1.4257(12)
C(2B)-C(15B)	1.5219(14)
C(2B)-C(9B)	1.5280(15)
O(3B)-C(4B)	1.4477(13)
C(4B)-C(5B)	1.5086(18)
C(4B)-C(8B)	1.5118(16)

C(4B)-H(4B)	1.0000
C(5B)-C(6B)	1.5098(17)
C(5B)-H(5BA)	0.9900
C(5B)-H(5BB)	0.9900
C(6B)-C(7B)	1.5086(16)
C(6B)-H(6B)	1.0000
C(7B)-H(7BA)	0.9800
C(7B)-H(7BB)	0.9800
C(7B)-H(7BC)	0.9800
C(8B)-H(8BA)	0.9800
C(8B)-H(8BB)	0.9800
C(8B)-H(8BC)	0.9800
C(9B)-C(14B)	1.3872(16)
C(9B)-C(10B)	1.3893(16)
C(10B)-C(11B)	1.3908(18)
C(10B)-H(10B)	0.9500
C(11B)-C(12B)	1.381(2)
C(11B)-H(11B)	0.9500
C(12B)-C(13B)	1.377(2)
C(12B)-H(12B)	0.9500
C(13B)-C(14B)	1.3884(17)
C(13B)-H(13B)	0.9500
C(14B)-H(14B)	0.9500
C(15B)-C(20B)	1.3848(14)
C(15B)-C(16B)	1.3966(15)
C(16B)-C(17B)	1.3785(15)
C(16B)-H(16B)	0.9500
C(17B)-C(18B)	1.3943(15)
C(17B)-H(17B)	0.9500
C(18B)-O(21B)	1.3708(13)
C(18B)-C(19B)	1.3835(15)
C(19B)-C(20B)	1.3945(15)
C(19B)-H(19B)	0.9500
C(20B)-H(20B)	0.9500
O(21B)-C(22B)	1.4242(14)
C(22B)-H(22D)	0.9800
C(22B)-H(22E)	0.9800
C(22B)-H(22F)	0.9800
O(1C)-C(2C)	1.4189(12)
O(1C)-C(6C)	1.4510(12)
C(2C)-O(3C)	1.4187(12)
C(2C)-C(15C)	1.5253(14)
C(2C)-C(9C)	1.5340(14)
O(3C)-C(4C)	1.4458(12)
C(4C)-C(8C)	1.5086(16)
C(4C)-C(5C)	1.5125(17)
C(4C)-H(4C)	1.0000
C(5C)-C(6C)	1.5142(16)
C(5C)-H(5CA)	0.9900
C(5C)-H(5CB)	0.9900
C(6C)-C(7C)	1.5068(16)
C(6C)-H(6C)	1.0000
C(7C)-H(7CA)	0.9800
C(7C)-H(7CB)	0.9800
C(7C)-H(7CC)	0.9800
C(8C)-H(8CA)	0.9800

C(8C)-H(8CB)	0.9800
C(8C)-H(8CC)	0.9800
C(9C)-C(10C)	1.3872(15)
C(9C)-C(14C)	1.3908(15)
C(10C)-C(11C)	1.3931(16)
C(10C)-H(10C)	0.9500
C(11C)-C(12C)	1.380(2)
C(11C)-H(11C)	0.9500
C(12C)-C(13C)	1.381(2)
C(12C)-H(12C)	0.9500
C(13C)-C(14C)	1.3882(17)
C(13C)-H(13C)	0.9500
C(14C)-H(14C)	0.9500
C(15C)-C(16C)	1.3852(15)
C(15C)-C(20C)	1.3876(15)
C(16C)-C(17C)	1.3923(15)
C(16C)-H(16C)	0.9500
C(17C)-C(18C)	1.3851(16)
C(17C)-H(17C)	0.9500
C(18C)-O(21C)	1.3678(13)
C(18C)-C(19C)	1.3876(16)
C(19C)-C(20C)	1.3844(15)
C(19C)-H(19C)	0.9500
C(20C)-H(20C)	0.9500
O(21C)-C(22C)	1.4291(16)
C(22C)-H(22G)	0.9800
C(22C)-H(22H)	0.9800
C(22C)-H(22I)	0.9800
C(2)-O(1)-C(6)	115.13(8)
O(1)-C(2)-O(3)	111.32(8)
O(1)-C(2)-C(15)	105.88(8)
O(3)-C(2)-C(15)	106.65(8)
O(1)-C(2)-C(9)	111.68(9)
O(3)-C(2)-C(9)	111.11(9)
C(15)-C(2)-C(9)	109.95(8)
C(2)-O(3)-C(4)	113.50(8)
O(3)-C(4)-C(8)	106.65(11)
O(3)-C(4)-C(5)	109.27(10)
C(8)-C(4)-C(5)	112.95(11)
O(3)-C(4)-H(4)	109.3
C(8)-C(4)-H(4)	109.3
C(5)-C(4)-H(4)	109.3
C(6)-C(5)-C(4)	110.48(9)
C(6)-C(5)-H(5A)	109.6
C(4)-C(5)-H(5A)	109.6
C(6)-C(5)-H(5B)	109.6
C(4)-C(5)-H(5B)	109.6
H(5A)-C(5)-H(5B)	108.1
O(1)-C(6)-C(7)	105.56(10)
O(1)-C(6)-C(5)	109.13(9)
C(7)-C(6)-C(5)	113.57(10)
O(1)-C(6)-H(6)	109.5
C(7)-C(6)-H(6)	109.5
C(5)-C(6)-H(6)	109.5
C(6)-C(7)-H(7A)	109.5

C(6)-C(7)-H(7B)	109.5
H(7A)-C(7)-H(7B)	109.5
C(6)-C(7)-H(7C)	109.5
H(7A)-C(7)-H(7C)	109.5
H(7B)-C(7)-H(7C)	109.5
C(4)-C(8)-H(8A)	109.5
C(4)-C(8)-H(8B)	109.5
H(8A)-C(8)-H(8B)	109.5
C(4)-C(8)-H(8C)	109.5
H(8A)-C(8)-H(8C)	109.5
H(8B)-C(8)-H(8C)	109.5
C(14)-C(9)-C(10)	119.23(11)
C(14)-C(9)-C(2)	120.39(10)
C(10)-C(9)-C(2)	120.27(10)
C(9)-C(10)-C(11)	120.20(13)
C(9)-C(10)-H(10)	119.9
C(11)-C(10)-H(10)	119.9
C(12)-C(11)-C(10)	120.39(13)
C(12)-C(11)-H(11)	119.8
C(10)-C(11)-H(11)	119.8
C(11)-C(12)-C(13)	119.65(12)
C(11)-C(12)-H(12)	120.2
C(13)-C(12)-H(12)	120.2
C(12)-C(13)-C(14)	120.48(13)
C(12)-C(13)-H(13)	119.8
C(14)-C(13)-H(13)	119.8
C(9)-C(14)-C(13)	120.05(12)
C(9)-C(14)-H(14)	120.0
C(13)-C(14)-H(14)	120.0
C(16)-C(15)-C(20)	118.04(10)
C(16)-C(15)-C(2)	120.89(10)
C(20)-C(15)-C(2)	121.07(9)
C(15)-C(16)-C(17)	121.63(10)
C(15)-C(16)-H(16)	119.2
C(17)-C(16)-H(16)	119.2
C(18)-C(17)-C(16)	119.54(10)
C(18)-C(17)-H(17)	120.2
C(16)-C(17)-H(17)	120.2
O(21)-C(18)-C(17)	124.86(10)
O(21)-C(18)-C(19)	115.82(10)
C(17)-C(18)-C(19)	119.32(10)
C(20)-C(19)-C(18)	120.62(11)
C(20)-C(19)-H(19)	119.7
C(18)-C(19)-H(19)	119.7
C(19)-C(20)-C(15)	120.84(10)
C(19)-C(20)-H(20)	119.6
C(15)-C(20)-H(20)	119.6
C(18)-O(21)-C(22)	117.59(9)
O(21)-C(22)-H(22A)	109.5
O(21)-C(22)-H(22B)	109.5
H(22A)-C(22)-H(22B)	109.5
O(21)-C(22)-H(22C)	109.5
H(22A)-C(22)-H(22C)	109.5
H(22B)-C(22)-H(22C)	109.5
C(2B)-O(1B)-C(6B)	114.02(8)
O(1B)-C(2B)-O(3B)	110.81(8)

O(1B)-C(2B)-C(15B)	105.61(8)
O(3B)-C(2B)-C(15B)	105.61(8)
O(1B)-C(2B)-C(9B)	110.65(8)
O(3B)-C(2B)-C(9B)	111.86(8)
C(15B)-C(2B)-C(9B)	112.03(8)
C(2B)-O(3B)-C(4B)	114.52(8)
O(3B)-C(4B)-C(5B)	109.54(9)
O(3B)-C(4B)-C(8B)	106.64(10)
C(5B)-C(4B)-C(8B)	113.35(11)
O(3B)-C(4B)-H(4B)	109.1
C(5B)-C(4B)-H(4B)	109.1
C(8B)-C(4B)-H(4B)	109.1
C(4B)-C(5B)-C(6B)	110.31(9)
C(4B)-C(5B)-H(5BA)	109.6
C(6B)-C(5B)-H(5BA)	109.6
C(4B)-C(5B)-H(5BB)	109.6
C(6B)-C(5B)-H(5BB)	109.6
H(5BA)-C(5B)-H(5BB)	108.1
O(1B)-C(6B)-C(7B)	106.56(9)
O(1B)-C(6B)-C(5B)	108.86(9)
C(7B)-C(6B)-C(5B)	113.92(11)
O(1B)-C(6B)-H(6B)	109.1
C(7B)-C(6B)-H(6B)	109.1
C(5B)-C(6B)-H(6B)	109.1
C(6B)-C(7B)-H(7BA)	109.5
C(6B)-C(7B)-H(7BB)	109.5
H(7BA)-C(7B)-H(7BB)	109.5
C(6B)-C(7B)-H(7BC)	109.5
H(7BA)-C(7B)-H(7BC)	109.5
H(7BB)-C(7B)-H(7BC)	109.5
C(4B)-C(8B)-H(8BA)	109.5
C(4B)-C(8B)-H(8BB)	109.5
H(8BA)-C(8B)-H(8BB)	109.5
C(4B)-C(8B)-H(8BC)	109.5
H(8BA)-C(8B)-H(8BC)	109.5
H(8BB)-C(8B)-H(8BC)	109.5
C(14B)-C(9B)-C(10B)	118.92(11)
C(14B)-C(9B)-C(2B)	121.00(10)
C(10B)-C(9B)-C(2B)	119.93(10)
C(9B)-C(10B)-C(11B)	120.56(12)
C(9B)-C(10B)-H(10B)	119.7
C(11B)-C(10B)-H(10B)	119.7
C(12B)-C(11B)-C(10B)	119.94(13)
C(12B)-C(11B)-H(11B)	120.0
C(10B)-C(11B)-H(11B)	120.0
C(13B)-C(12B)-C(11B)	119.84(12)
C(13B)-C(12B)-H(12B)	120.1
C(11B)-C(12B)-H(12B)	120.1
C(12B)-C(13B)-C(14B)	120.41(13)
C(12B)-C(13B)-H(13B)	119.8
C(14B)-C(13B)-H(13B)	119.8
C(9B)-C(14B)-C(13B)	120.33(12)
C(9B)-C(14B)-H(14B)	119.8
C(13B)-C(14B)-H(14B)	119.8
C(20B)-C(15B)-C(16B)	118.21(10)
C(20B)-C(15B)-C(2B)	123.24(9)

C(16B)-C(15B)-C(2B)	118.55(9)
C(17B)-C(16B)-C(15B)	121.06(10)
C(17B)-C(16B)-H(16B)	119.5
C(15B)-C(16B)-H(16B)	119.5
C(16B)-C(17B)-C(18B)	119.95(10)
C(16B)-C(17B)-H(17B)	120.0
C(18B)-C(17B)-H(17B)	120.0
O(21B)-C(18B)-C(19B)	124.60(10)
O(21B)-C(18B)-C(17B)	115.42(9)
C(19B)-C(18B)-C(17B)	119.97(10)
C(18B)-C(19B)-C(20B)	119.31(10)
C(18B)-C(19B)-H(19B)	120.3
C(20B)-C(19B)-H(19B)	120.3
C(15B)-C(20B)-C(19B)	121.49(10)
C(15B)-C(20B)-H(20B)	119.3
C(19B)-C(20B)-H(20B)	119.3
C(18B)-O(21B)-C(22B)	117.84(9)
O(21B)-C(22B)-H(22D)	109.5
O(21B)-C(22B)-H(22E)	109.5
H(22D)-C(22B)-H(22E)	109.5
O(21B)-C(22B)-H(22F)	109.5
H(22D)-C(22B)-H(22F)	109.5
H(22E)-C(22B)-H(22F)	109.5
C(2C)-O(1C)-C(6C)	114.46(8)
O(3C)-C(2C)-O(1C)	111.26(8)
O(3C)-C(2C)-C(15C)	106.84(8)
O(1C)-C(2C)-C(15C)	105.95(8)
O(3C)-C(2C)-C(9C)	110.93(8)
O(1C)-C(2C)-C(9C)	111.60(8)
C(15C)-C(2C)-C(9C)	110.03(8)
C(2C)-O(3C)-C(4C)	113.93(8)
O(3C)-C(4C)-C(8C)	106.25(9)
O(3C)-C(4C)-C(5C)	108.82(9)
C(8C)-C(4C)-C(5C)	113.67(10)
O(3C)-C(4C)-H(4C)	109.3
C(8C)-C(4C)-H(4C)	109.3
C(5C)-C(4C)-H(4C)	109.3
C(4C)-C(5C)-C(6C)	110.35(9)
C(4C)-C(5C)-H(5CA)	109.6
C(6C)-C(5C)-H(5CA)	109.6
C(4C)-C(5C)-H(5CB)	109.6
C(6C)-C(5C)-H(5CB)	109.6
H(5CA)-C(5C)-H(5CB)	108.1
O(1C)-C(6C)-C(7C)	106.07(9)
O(1C)-C(6C)-C(5C)	109.25(8)
C(7C)-C(6C)-C(5C)	113.58(10)
O(1C)-C(6C)-H(6C)	109.3
C(7C)-C(6C)-H(6C)	109.3
C(5C)-C(6C)-H(6C)	109.3
C(6C)-C(7C)-H(7CA)	109.5
C(6C)-C(7C)-H(7CB)	109.5
H(7CA)-C(7C)-H(7CB)	109.5
C(6C)-C(7C)-H(7CC)	109.5
H(7CA)-C(7C)-H(7CC)	109.5
H(7CB)-C(7C)-H(7CC)	109.5
C(4C)-C(8C)-H(8CA)	109.5

C(4C)-C(8C)-H(8CB)	109.5
H(8CA)-C(8C)-H(8CB)	109.5
C(4C)-C(8C)-H(8CC)	109.5
H(8CA)-C(8C)-H(8CC)	109.5
H(8CB)-C(8C)-H(8CC)	109.5
C(10C)-C(9C)-C(14C)	119.26(10)
C(10C)-C(9C)-C(2C)	121.39(9)
C(14C)-C(9C)-C(2C)	119.26(10)
C(9C)-C(10C)-C(11C)	119.97(11)
C(9C)-C(10C)-H(10C)	120.0
C(11C)-C(10C)-H(10C)	120.0
C(12C)-C(11C)-C(10C)	120.58(12)
C(12C)-C(11C)-H(11C)	119.7
C(10C)-C(11C)-H(11C)	119.7
C(11C)-C(12C)-C(13C)	119.50(11)
C(11C)-C(12C)-H(12C)	120.2
C(13C)-C(12C)-H(12C)	120.2
C(12C)-C(13C)-C(14C)	120.39(12)
C(12C)-C(13C)-H(13C)	119.8
C(14C)-C(13C)-H(13C)	119.8
C(13C)-C(14C)-C(9C)	120.29(12)
C(13C)-C(14C)-H(14C)	119.9
C(9C)-C(14C)-H(14C)	119.9
C(16C)-C(15C)-C(20C)	118.26(10)
C(16C)-C(15C)-C(2C)	120.06(9)
C(20C)-C(15C)-C(2C)	121.67(9)
C(15C)-C(16C)-C(17C)	121.66(10)
C(15C)-C(16C)-H(16C)	119.2
C(17C)-C(16C)-H(16C)	119.2
C(18C)-C(17C)-C(16C)	119.34(10)
C(18C)-C(17C)-H(17C)	120.3
C(16C)-C(17C)-H(17C)	120.3
O(21C)-C(18C)-C(17C)	124.76(10)
O(21C)-C(18C)-C(19C)	115.78(10)
C(17C)-C(18C)-C(19C)	119.46(10)
C(20C)-C(19C)-C(18C)	120.59(10)
C(20C)-C(19C)-H(19C)	119.7
C(18C)-C(19C)-H(19C)	119.7
C(19C)-C(20C)-C(15C)	120.67(10)
C(19C)-C(20C)-H(20C)	119.7
C(15C)-C(20C)-H(20C)	119.7
C(18C)-O(21C)-C(22C)	117.30(10)
O(21C)-C(22C)-H(22G)	109.5
O(21C)-C(22C)-H(22H)	109.5
H(22G)-C(22C)-H(22H)	109.5
O(21C)-C(22C)-H(22I)	109.5
H(22G)-C(22C)-H(22I)	109.5
H(22H)-C(22C)-H(22I)	109.5

Symmetry transformations used to generate equivalent atoms:

Anisotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for compound **4**. The anisotropic displacement factor exponent takes the form: $-2\pi^2 [h^2 a^{*2} U^{11} + \dots + 2 h k a^* b^* U^{12}]$

	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
O(1)	22(1)	36(1)	23(1)	-7(1)	5(1)	0(1)
C(2)	20(1)	28(1)	24(1)	-2(1)	2(1)	4(1)
O(3)	28(1)	34(1)	25(1)	2(1)	2(1)	10(1)
C(4)	31(1)	49(1)	25(1)	8(1)	1(1)	9(1)
C(5)	25(1)	60(1)	24(1)	1(1)	0(1)	10(1)
C(6)	22(1)	53(1)	22(1)	-8(1)	3(1)	6(1)
C(7)	32(1)	60(1)	37(1)	-20(1)	2(1)	3(1)
C(8)	68(1)	52(1)	44(1)	12(1)	-10(1)	17(1)
C(9)	20(1)	40(1)	19(1)	4(1)	3(1)	5(1)
C(10)	27(1)	45(1)	27(1)	4(1)	2(1)	-2(1)
C(11)	24(1)	77(1)	30(1)	9(1)	1(1)	-8(1)
C(12)	19(1)	107(1)	28(1)	18(1)	5(1)	14(1)
C(13)	36(1)	77(1)	28(1)	16(1)	10(1)	31(1)
C(14)	30(1)	45(1)	24(1)	9(1)	7(1)	14(1)
C(15)	18(1)	29(1)	24(1)	-1(1)	3(1)	5(1)
C(16)	39(1)	27(1)	30(1)	-2(1)	11(1)	-3(1)
C(17)	44(1)	26(1)	28(1)	-6(1)	10(1)	-1(1)
C(18)	33(1)	30(1)	24(1)	1(1)	8(1)	6(1)
C(19)	51(1)	24(1)	32(1)	0(1)	12(1)	-2(1)
C(20)	41(1)	26(1)	28(1)	-5(1)	7(1)	1(1)
O(21)	64(1)	31(1)	26(1)	0(1)	17(1)	1(1)
C(22)	69(1)	38(1)	26(1)	-3(1)	16(1)	7(1)
O(1B)	22(1)	23(1)	31(1)	-1(1)	6(1)	1(1)
C(2B)	23(1)	25(1)	21(1)	-1(1)	6(1)	2(1)
O(3B)	33(1)	26(1)	23(1)	-2(1)	10(1)	3(1)
C(4B)	42(1)	26(1)	28(1)	-5(1)	9(1)	4(1)
C(5B)	42(1)	28(1)	31(1)	-6(1)	1(1)	-1(1)
C(6B)	27(1)	22(1)	36(1)	0(1)	4(1)	0(1)
C(7B)	27(1)	32(1)	65(1)	4(1)	3(1)	0(1)
C(8B)	66(1)	44(1)	36(1)	-11(1)	22(1)	5(1)
C(9B)	30(1)	21(1)	24(1)	0(1)	4(1)	2(1)
C(10B)	41(1)	32(1)	27(1)	2(1)	9(1)	5(1)
C(11B)	63(1)	40(1)	27(1)	8(1)	7(1)	3(1)
C(12B)	59(1)	38(1)	37(1)	11(1)	-9(1)	7(1)
C(13B)	39(1)	38(1)	51(1)	8(1)	-2(1)	11(1)
C(14B)	31(1)	31(1)	36(1)	6(1)	6(1)	7(1)
C(15B)	22(1)	24(1)	19(1)	1(1)	8(1)	3(1)
C(16B)	26(1)	28(1)	20(1)	1(1)	2(1)	0(1)
C(17B)	28(1)	28(1)	24(1)	6(1)	1(1)	4(1)
C(18B)	27(1)	22(1)	25(1)	3(1)	7(1)	1(1)
C(19B)	23(1)	28(1)	23(1)	0(1)	2(1)	1(1)
C(20B)	23(1)	26(1)	22(1)	2(1)	3(1)	5(1)
O(21B)	41(1)	22(1)	35(1)	2(1)	-4(1)	0(1)
C(22B)	44(1)	26(1)	36(1)	0(1)	-1(1)	-5(1)
O(1C)	23(1)	27(1)	20(1)	4(1)	5(1)	7(1)
C(2C)	20(1)	21(1)	20(1)	-1(1)	2(1)	2(1)
O(3C)	27(1)	27(1)	18(1)	-1(1)	4(1)	-3(1)
C(4C)	30(1)	35(1)	19(1)	-3(1)	4(1)	-2(1)
C(5C)	25(1)	43(1)	20(1)	3(1)	2(1)	2(1)
C(6C)	23(1)	34(1)	21(1)	7(1)	5(1)	5(1)
C(7C)	36(1)	41(1)	33(1)	12(1)	4(1)	12(1)

C(8C)	60(1)	42(1)	26(1)	-7(1)	1(1)	-11(1)
C(9C)	20(1)	31(1)	16(1)	0(1)	3(1)	4(1)
C(10C)	24(1)	34(1)	21(1)	-2(1)	3(1)	0(1)
C(11C)	24(1)	58(1)	20(1)	-2(1)	3(1)	-8(1)
C(12C)	20(1)	82(1)	23(1)	-1(1)	4(1)	12(1)
C(13C)	34(1)	60(1)	32(1)	1(1)	6(1)	26(1)
C(14C)	31(1)	36(1)	27(1)	0(1)	5(1)	12(1)
C(15C)	18(1)	25(1)	21(1)	2(1)	4(1)	5(1)
C(16C)	33(1)	27(1)	25(1)	0(1)	8(1)	-1(1)
C(17C)	41(1)	26(1)	24(1)	-4(1)	6(1)	4(1)
C(18C)	38(1)	31(1)	21(1)	4(1)	8(1)	11(1)
C(19C)	48(1)	26(1)	27(1)	5(1)	13(1)	3(1)
C(20C)	36(1)	23(1)	25(1)	1(1)	7(1)	4(1)
O(21C)	70(1)	36(1)	23(1)	2(1)	18(1)	8(1)
C(22C)	75(1)	47(1)	24(1)	-4(1)	16(1)	12(1)

Hydrogen coordinates ($\times 10^4$) and isotropic displacement parameters ($\text{\AA}^2 \times 10^{-3}$)
for compound **4**.

	x	y	z	U(eq)
H(4)	7819	1112	6245	42
H(5A)	10049	1811	7077	44
H(5B)	11249	1889	6507	44
H(6)	8389	2744	6477	39
H(7A)	10736	3524	7177	67
H(7B)	10356	3995	6450	67
H(7C)	11835	3428	6584	67
H(8A)	8836	-134	5984	85
H(8B)	9687	193	6772	85
H(8C)	10716	346	6146	85
H(10)	5830	798	5030	41
H(11)	2981	789	5018	55
H(12)	1943	2051	5174	61
H(13)	3760	3325	5362	53
H(14)	6622	3342	5400	38
H(16)	7788	997	4076	38
H(17)	8216	1169	2921	39
H(19)	9996	3639	3405	43
H(20)	9550	3464	4550	39
H(22A)	9433	2115	1438	66
H(22B)	7936	1698	1803	66
H(22C)	9772	1452	2044	66
H(4B)	6624	5747	8380	38
H(5BA)	9618	5240	9160	42
H(5BB)	9387	6187	8933	42
H(6B)	9094	5790	7738	35
H(7BA)	11953	5159	8509	64
H(7BB)	11922	6116	8273	64
H(7BC)	11715	5366	7691	64
H(8BA)	7071	4991	9724	71
H(8BB)	5357	5263	9319	71
H(8BC)	6914	5973	9619	71
H(10B)	8105	4771	6571	40
H(11B)	6682	5392	5595	52
H(12B)	4046	5764	5614	56
H(13B)	2830	5508	6601	52
H(14B)	4237	4884	7576	39
H(16B)	8716	3135	8483	30
H(17B)	8263	1667	8352	33
H(19B)	4495	1799	6697	30
H(20B)	4933	3277	6850	29
H(22D)	5112	478	6462	56
H(22E)	3853	389	7007	56
H(22F)	5009	-327	6946	56
H(4C)	5327	8874	11265	34
H(5CA)	7187	8091	11957	36
H(5CB)	8387	8165	11387	36
H(6C)	5066	7243	11174	31
H(7CA)	6334	6050	10964	55
H(7CB)	7068	6435	11746	55
H(7CC)	8139	6613	11137	55

H(8CA)	7649	9746	11967	68
H(8CB)	6959	10194	11258	68
H(8CC)	8620	9761	11319	68
H(10C)	3073	6814	10106	32
H(11C)	219	6774	10107	42
H(12C)	-969	8022	10048	50
H(13C)	701	9317	9992	49
H(14C)	3559	9370	10012	37
H(16C)	4690	6975	8997	34
H(17C)	5057	7007	7826	37
H(19C)	7203	9455	8161	40
H(20C)	6813	9417	9324	33
H(22G)	6326	7735	6284	71
H(22H)	4813	7417	6676	71
H(22I)	6607	7131	6937	71

References Chapter II Section 2.1

- ¹ Bailey, W. F.; Lambert, K. M.; Wiberg, K. B.; Mercado, B. Q. *J. Org. Chem.* **2015**, *80*, 4108–4115.
- ² Pritchard, J. G.; Vollmer, R. L. *J. Org. Chem.* **1963**, *28*, 1545.
- ³ Davies, H. M. L.; Nagashima, T.; Kino, J. K. *Org. Lett.* **2000**, *2*, 823
- ⁴ The standard deviation from the mean (root mean square deviation) was determined for each series of measurements and this value was propagated to give the errors reported in Table 1. See, H. Margenau, H.; Murphy, G. M. *The Mathematics of Chemistry and Physics*; Van Nostrand: Princeton, N.J., 1968, pp. 504-515.
- ⁵ Sheldrick, G. *Acta Cryst., Section A* **2008**, *64*, 112.
- ⁶ These data can be obtained free of charge from The Cambridge Crystallographic Data Center via www.ccdc.cam.ac.uk/data_request/cif.
- ⁷ Gaussian 09 Revision D.01, Frisch, M. J.; Trucks, G. W.; Schlegel, H. B.; Scuseria, G. E.; Robb, M. A.; Cheeseman, J. R.; Scalmani, G.; Barone, V.; Mennucci, B.; Petersson, G. A.; Nakatsuji, H.; Caricato, M.; Hratchian, H. P.; Li, X.; Izmaylov, A. F.; Bloino, J.; Zheng, G.; Sonnenberg, J. L.; Hada, M.; Ehara, M.; Toyota, K.; Fukuda, R.; Hasegawa, J.; Ishida, M.; Nakajima, T.; Honda, Y.; Kitao, O.; Nakai, H.; Vreven, T.; Montgomery, Jr., J. A.; Peralta, J. E.; Ogliaro, F.; Bearpark, M.; Heyd, J. J.; Brothers, E.; Kudin, K. N.; Staroverov, V. N.; Kobayashi, R.; Normand, J.; Raghavachari, K.; Rendell, A.; Burant, J. C.; Iyengar, S. S.; Tomasi, J.; Cossi, M.; Rega, N.; Millam, J. M.; Klene, M.; Knox, J. E.; Cross, J. B.; Bakken, V.; Adamo, C.; Jaramillo, J.; Gomperts, R.; Stratmann, R. E.; Yazyev, O.; Austin, A. J.; Cammi, R.; Pomelli, C.; Ochterski, J. W.; Martin, M. L.; Morokuma, K.; Zakrzewski, V. G.; Voth, G. A.; Salvador, P.; Dannenberg, J. J.; Dapprich, S.; Daniels, A. D.; Farkas, O.; Foresman, J. B.; Ortiz, J. V.; Cioslowski, J.; Fox, D. J. Gaussian, Inc., Wallingford, CT 2009.
- ⁸ NOTE: Energy differences are calculated as **B** \rightarrow **A**; hence energy differences have a sign opposite of that in Table 1-3
- ⁹ NOTE: Energy differences are calculated as **B** \rightarrow **A**; hence energy differences have a sign opposite of that in Table 1-2

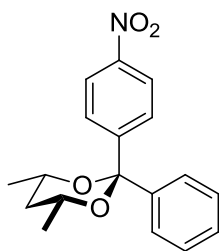


Current Data Parameters
NAME KL1-33-5B
EXPNO 1
PROCNO 1

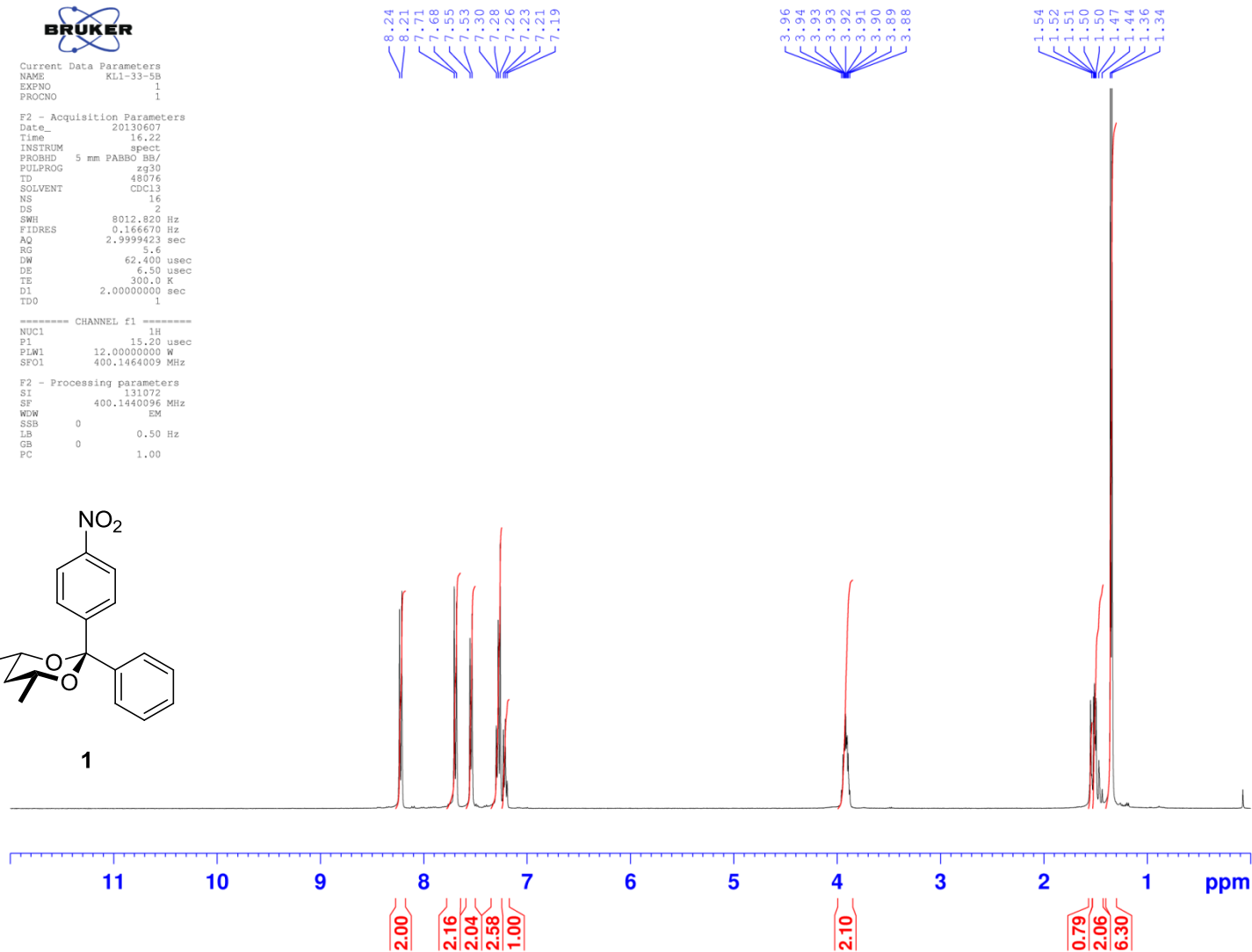
F2 - Acquisition Parameters
Date_ 20130607
Time 16.22
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 5.6
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

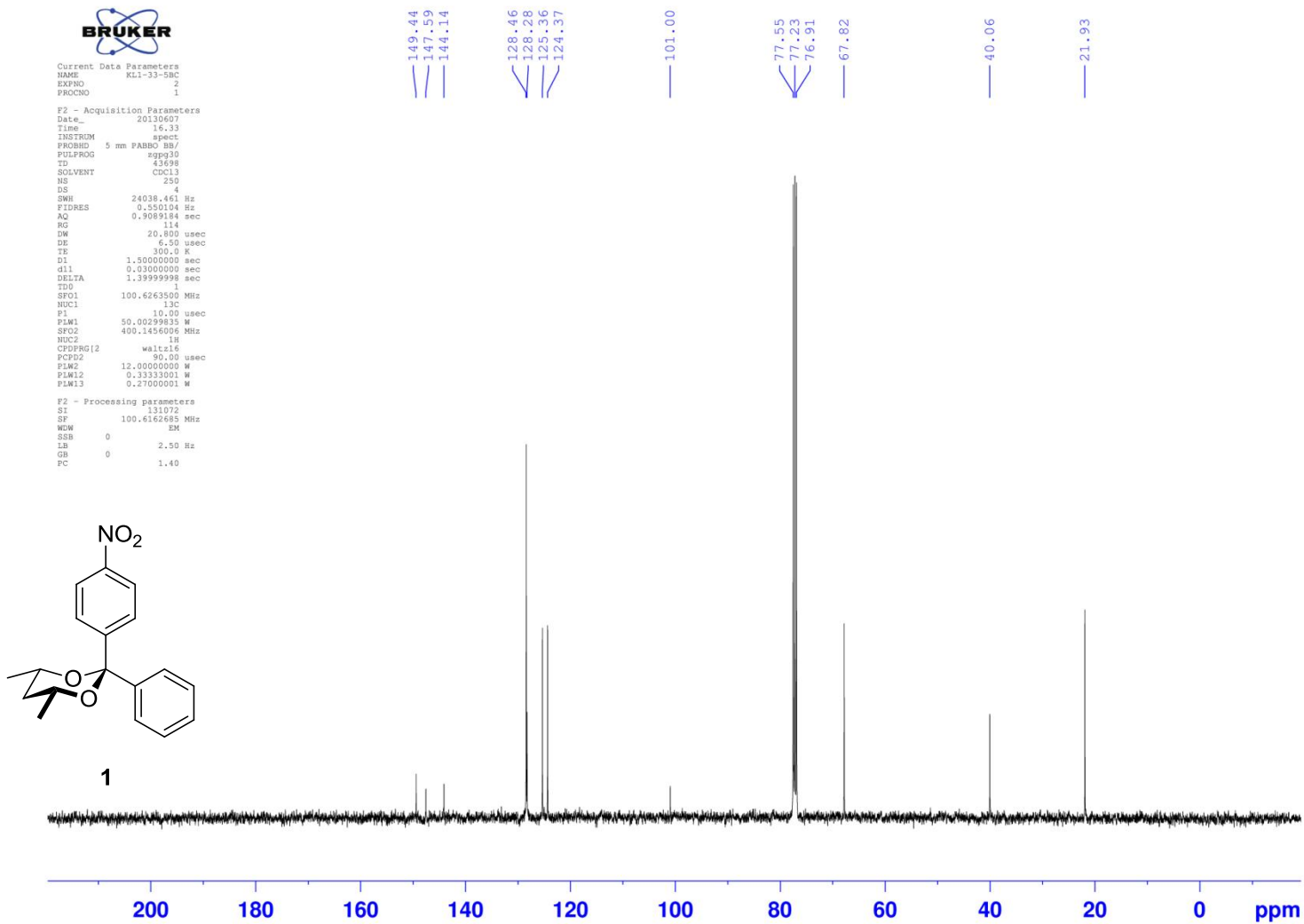
===== CHANNEL f1 =====
NUC1 1H
P1 15.20 usec
PLW1 12.00000000 W
SFO1 400.1464009 MHz

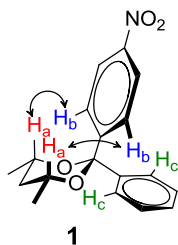
F2 - Processing parameters
SI 131072
SF 400.1440096 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00



1







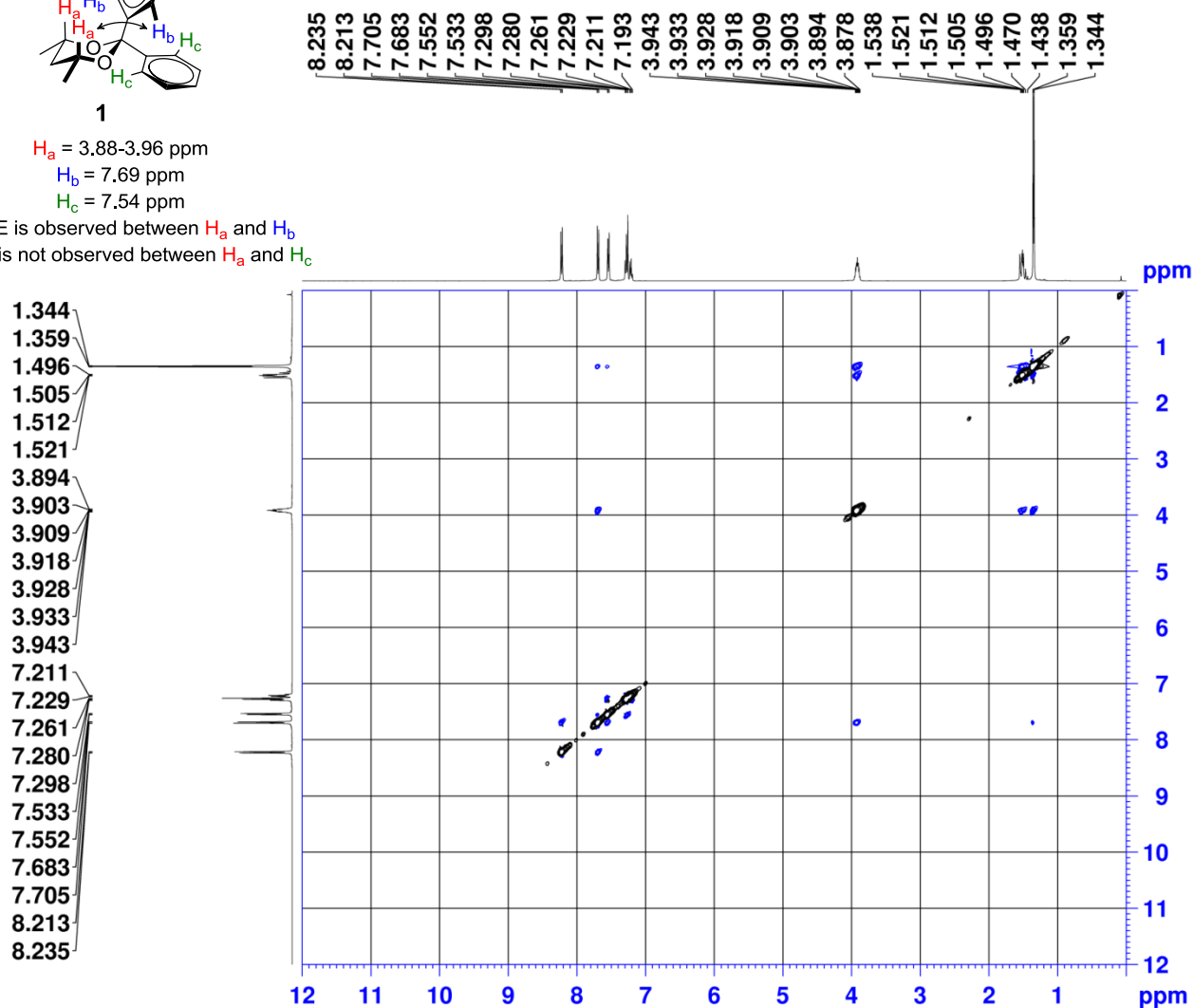
$H_a = 3.88\text{--}3.96\text{ ppm}$

$H_b = 7.69\text{ ppm}$

$H_c = 7.54\text{ ppm}$

A NOE is observed between H_a and H_b

A NOE is not observed between H_a and H_c



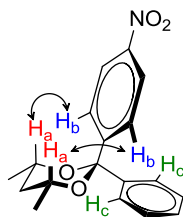
Current Data Parameters
NAME KL1-33-NOESY-ExptB-processed
EXPNO 2
PROCNO 1

F2 - Acquisition Parameters
Date_ 20130713
Time 19.57
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpph
TD 2670
SOLVENT CDCl3
NS 8
DS 32
SWH 8012.820 Hz
FIDRES 3.001056 Hz
AQ 0.1666080 sec
RG 40.3
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
d0 -0.00001910 sec
D1 2.00000000 sec
D8 0.69999999 sec
d11 0.03000000 sec
d12 0.00002000 sec
D16 0.00020000 sec
In0 0 sec
STICNT 128
TAU 0.34880000 sec
d0orig -0.00001910 sec
phloop 0
t1loop 0
SFO1 400.1464009 MHz
NUC1 1H
P1 15.00 usec
p2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W
GPNAM[1] SMSQ10.100
GP21 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 668
SFO1 400.1464 MHz
FIDRES 11.995211 Hz
SW 20.025 ppm
PnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440073 MHz
WDW QSI
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440076 MHz
WDW USER
SSB 2
LB 0 Hz
GB 0



1

H_a = 3.88-3.96 ppm

H_b = 7.69 ppm

H_c = 7.54 ppm

A NOE is observed between H_a and H_b

A NOE is not observed between H_a and H_c

3.958
3.943
3.933
3.928
3.918
3.909
3.903
3.894
3.878



Current Data Parameters
NAME KL1-33-NOESY-ExptB-processed
EXPNO 2
PROCNO 1

F2 - Acquisition Parameters
Date_ 20130713
Time 19.57
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpph
TD 2670
SOLVENT CDCl3
NS 8
DS 32
SWH 8012.820 Hz
FIDRES 3.001056 Hz
AQ 0.1666080 sec
RG 40.3
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
d0 -0.00001910 sec
D1 2.00000000 sec
D8 0.69999999 sec
d11 0.03000000 sec
d12 0.00002000 sec
D16 0.00020000 sec
in0 0 sec
STICNT 128
TAU 0.34880000 sec
d0orig -0.00001910 sec
philoop 0
t1loop 0
SFO1 400.1464009 MHz
NUC1 1H
P1 15.00 usec
p2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W
GPNAM[1] SMSQ10.100
GP21 40.00 %
P16 1000.00 usec

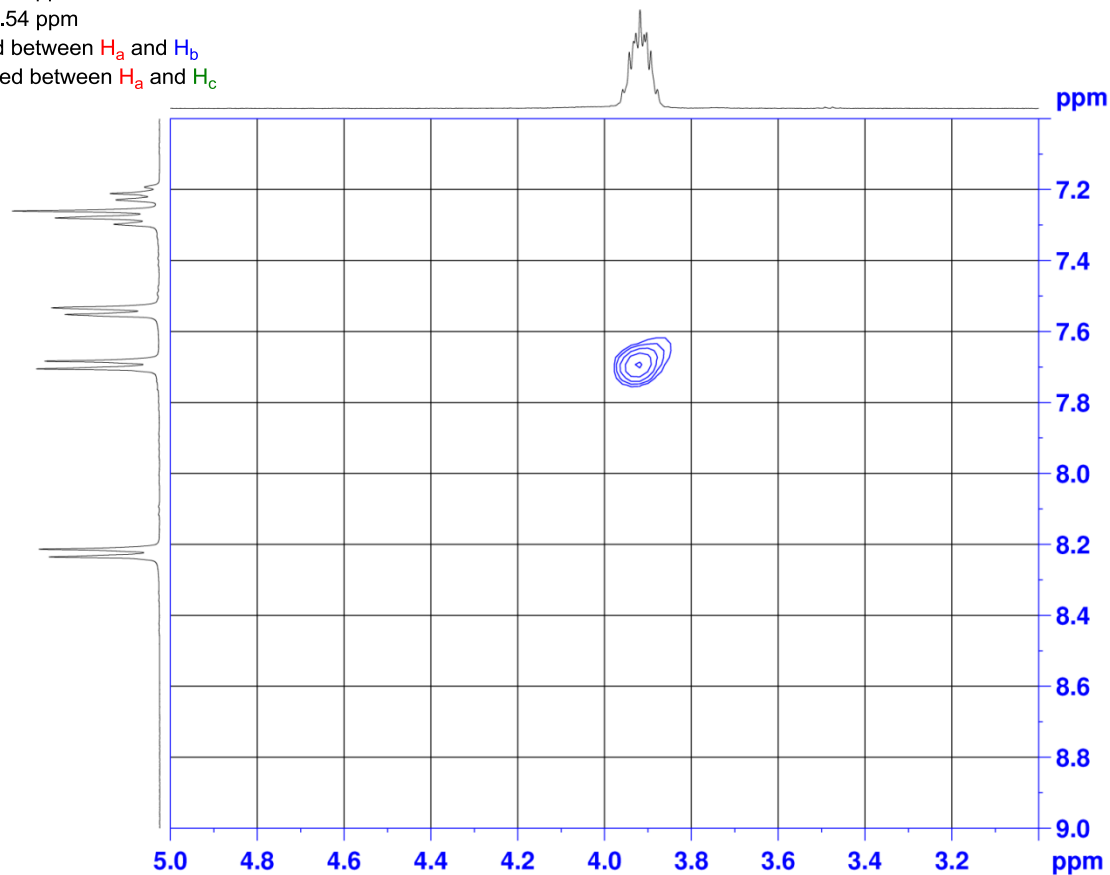
F1 - Acquisition parameters
TD 668
SFO1 400.1464 MHz
FIDRES 11.995211 Hz
SW 20.025 ppm
PnMODE States-TPPI

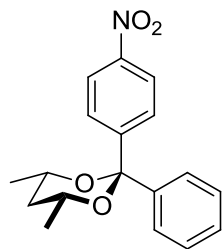
F2 - Processing parameters
SI 1024
SF 400.1440073 MHz
WDW QSI
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440076 MHz
WDW USER
SSB 2
LB 0 Hz
GB 0

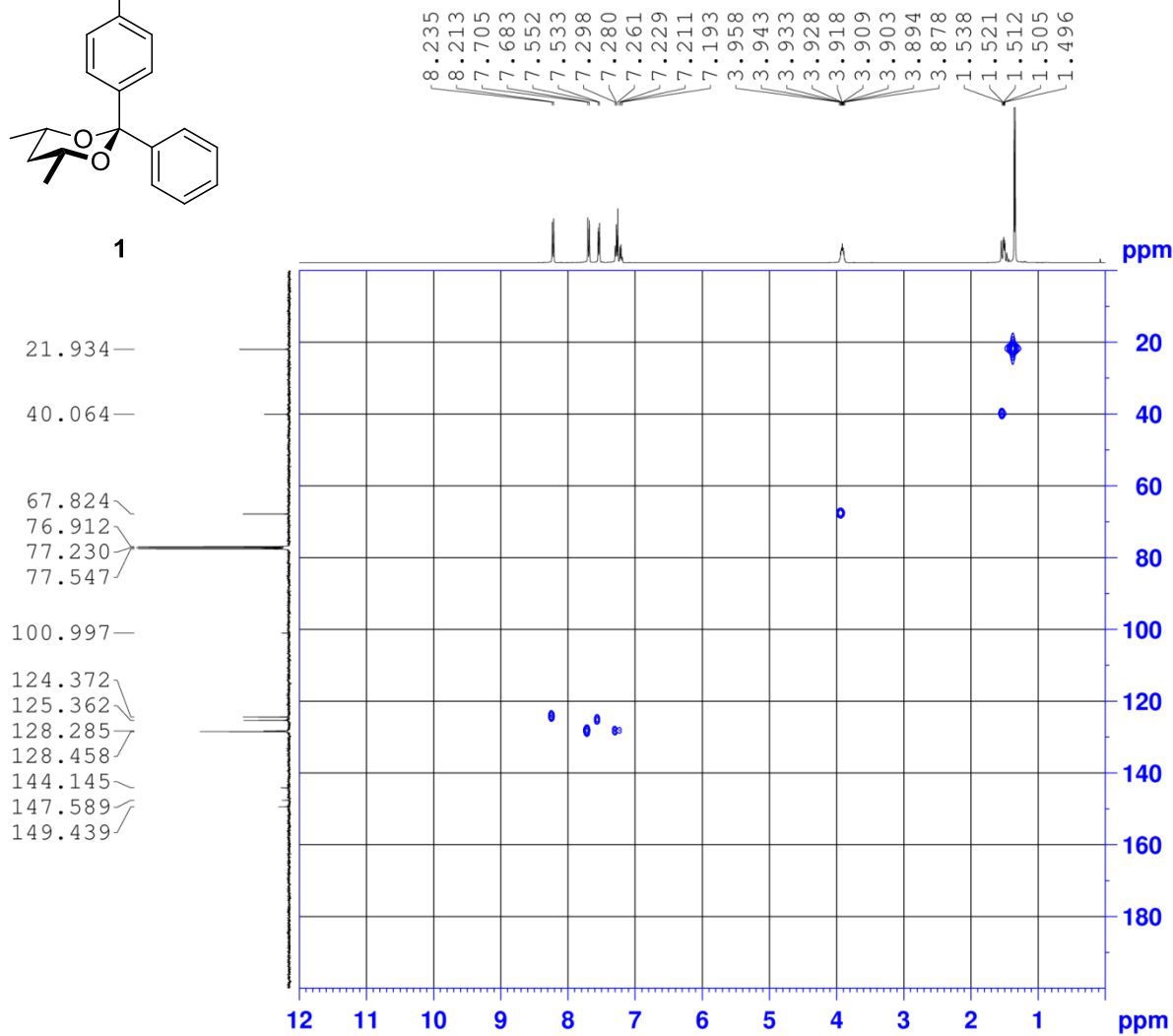
7.211
7.229
7.261
7.280
7.298
7.533
7.552
7.683
7.705

8.213
8.235





1



Current Data Parameters
NAME NO2-ax-isomer-HSQC-proce
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20131121
Time 16.36
INSTRUM spect
PROBHD 5 mm PASAD BB/
PULPROG hsqcetgp
TD 1024
SOLVENT CDCl3
NS 2
DS 16
SWH 5341.880 Hz
FIDRES 5.216680 Hz
AQ 0.8958464 sec
RG 203
DW 93.600 usec
DE 6.50 usec
TE 298.0 K
CNST2 145.0000000
d0 0.00000000 sec
d1 1.50000000 sec
d4 0.00172414 sec
d11 0.03000000 sec
d16 0.00020000 sec
DELTA 0.00123600 sec
DELTA1 0.00071919 sec
in0 0 sec
STICNT 128
ZGPTNS
d0orig 0.00000300 sec
philoop 0
t1loop 0
SF01 400.1464057 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P28 1000.00 usec
PLW1 12.00000000 W
SF02 100.6237933 MHz
NUC2 13C
CPDPRG2 garp
P3 10.00 usec
P4 20.00 usec
PCPD2 80.00 usec
PLW2 50.00000000 W
PLW12 0.78125000 W
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPZ1 80.00 %
GPZ2 20.10 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 116
SF01 100.6238 MHz
FIDRES 143.683182 Hz
SW 165.639 ppm
FnMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162890 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0

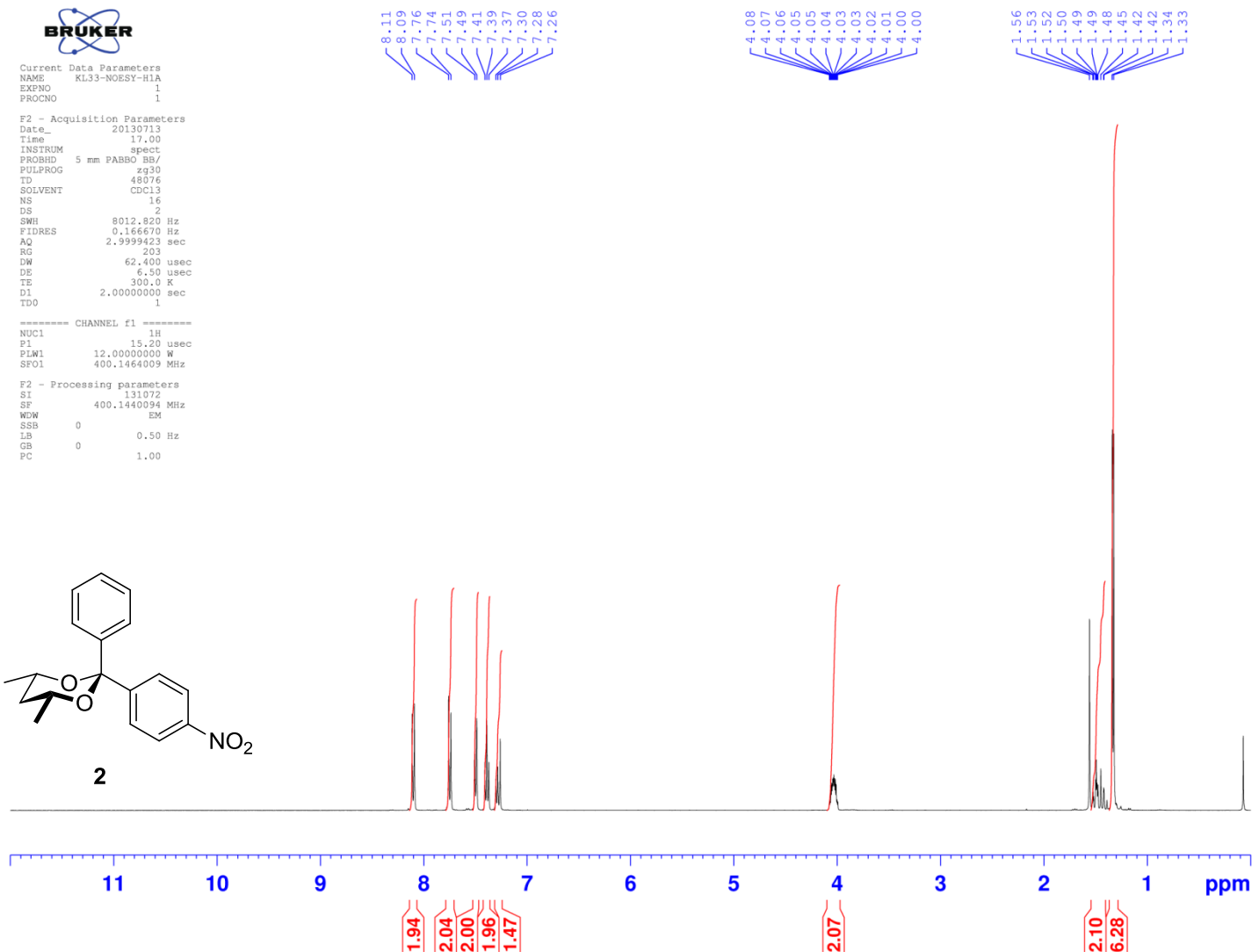
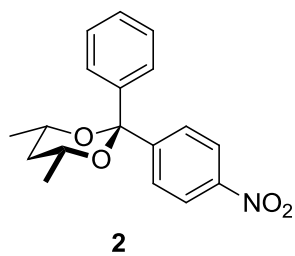


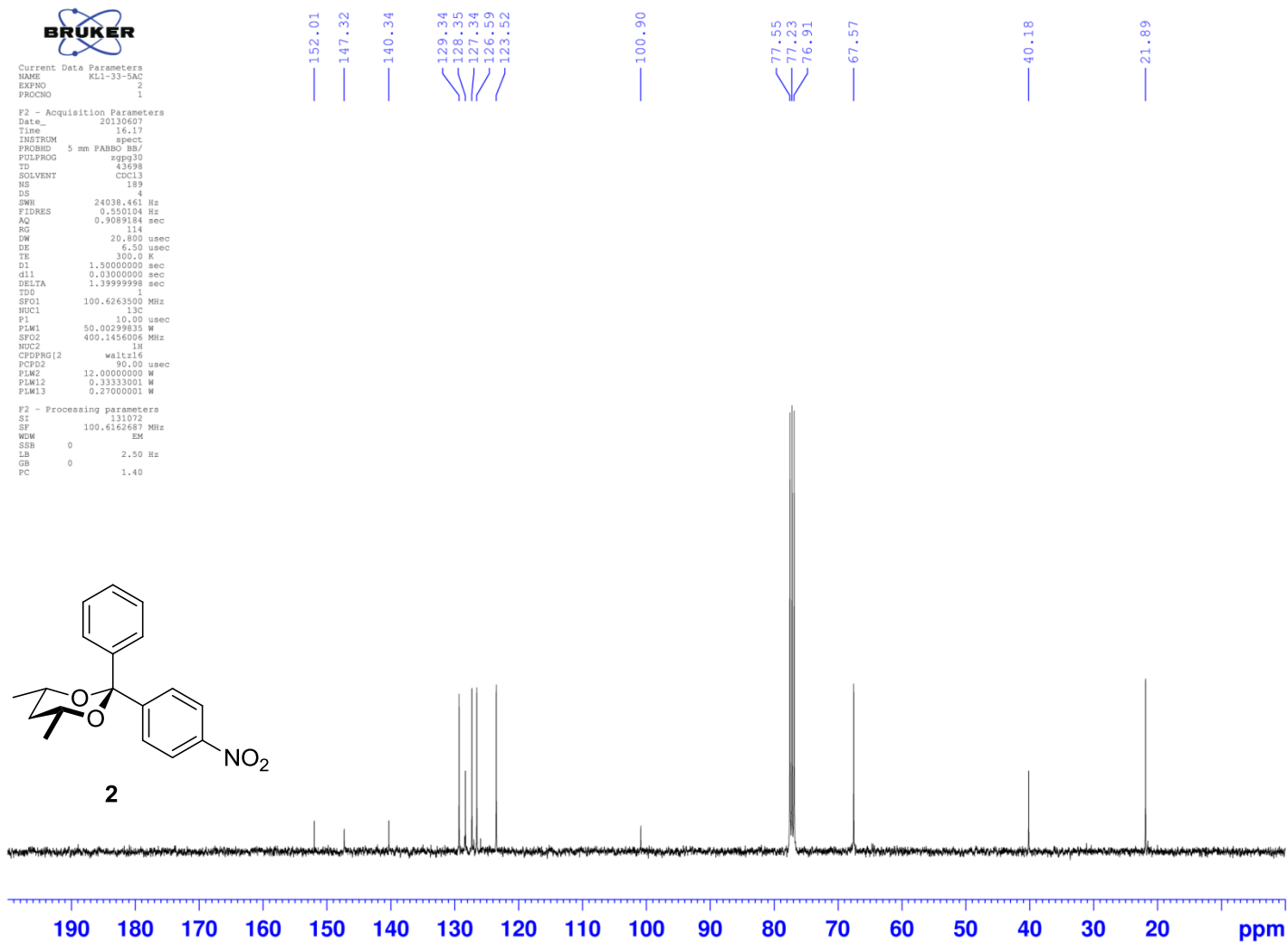
Current Data Parameters
NAME KL33-NOESY-H1A
EXPNO 1
PROCNO 1

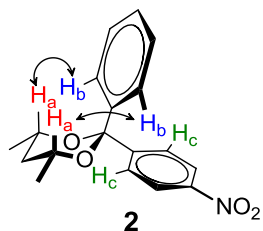
F2 - Acquisition Parameters
Date_ 20130713
Time 17.00
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 203
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
NUC1 1H
P1 15.20 usec
PLW1 12.00000000 W
SFO1 400.1464009 MHz

F2 - Processing parameters
SI 131072
SF 400.1440094 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00







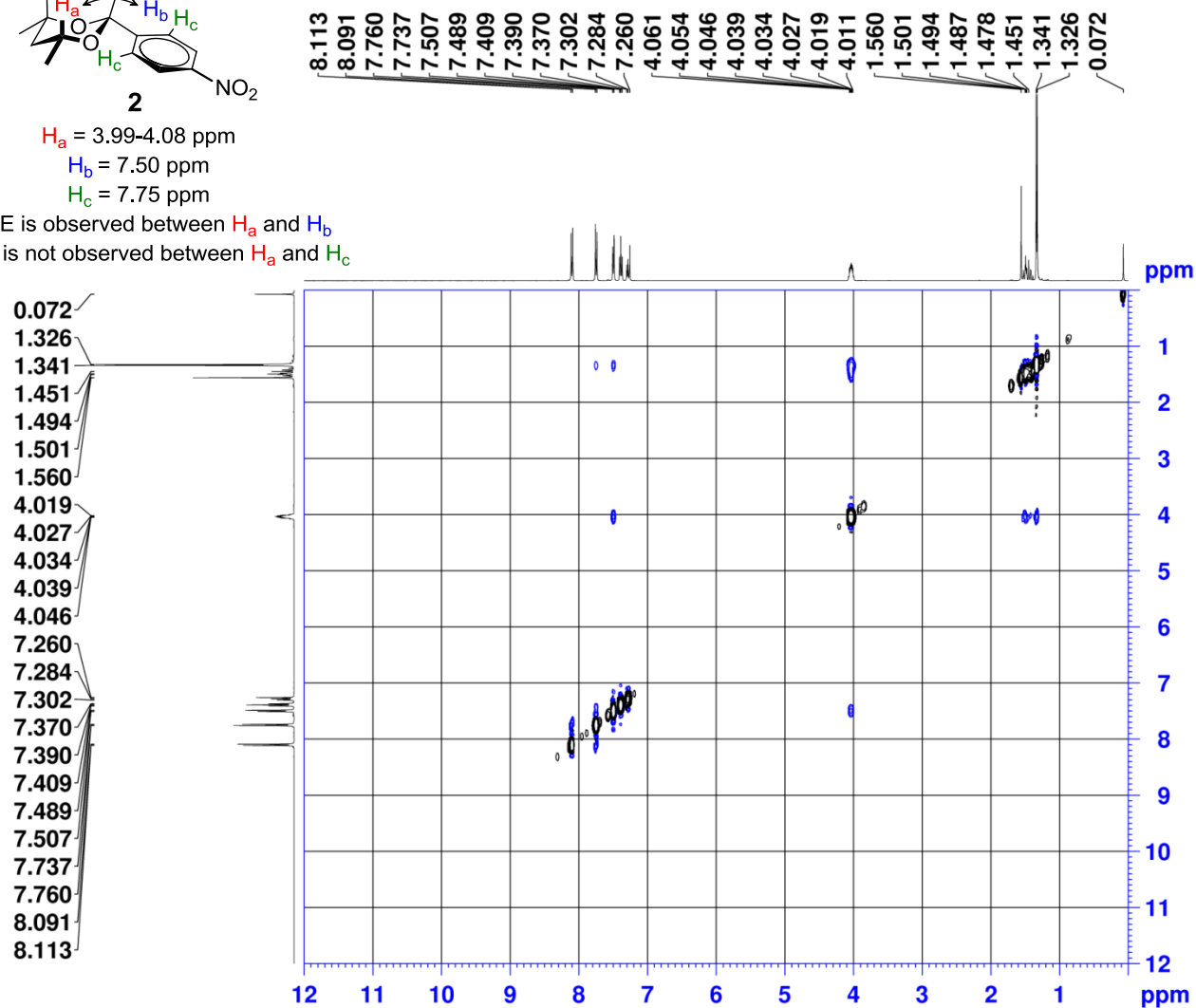
$H_a = 3.99\text{--}4.08\text{ ppm}$

$H_b = 7.50\text{ ppm}$

$H_c = 7.75\text{ ppm}$

A NOE is observed between H_a and H_b

A NOE is not observed between H_a and H_c



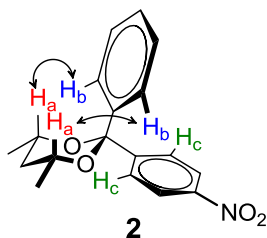
Current Data Parameters
NAME KL33-NOESY-exp-processedA
EXPNO 2
PROCNO 1

F2 - Acquisition Parameters
Date_ 20130713
Time 17.13
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesypphpg
TD 2670
SOLVENT CDCl3
NS 8
DS 32
SWH 8012.820 Hz
FIDRES 3.001056 Hz
AQ 0.1666080 sec
RG 203
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
d0 -0.00001910 sec
D1 2.00000000 sec
D8 0.69999999 sec
d11 0.03000000 sec
d12 0.00002000 sec
D16 0.00020000 sec
In0 0 sec
STICNT 128
TAU 0.34880000 sec
d0orig -0.00001910 sec
philoop 0
tllloop 0
SFO1 400.1464009 MHz
NUC1 1H
P1 15.00 usec
p2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1464 MHz
FIDRES 31.300001 Hz
SW 20.025 ppm
FhMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440071 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440056 MHz
WDW USER
SSB 2
LB 0 Hz
GB 0



$H_a = 3.99\text{--}4.08\text{ ppm}$

$H_b = 7.50\text{ ppm}$

$H_c = 7.75\text{ ppm}$

A NOE is observed between H_a and H_b

A NOE is not observed between H_a and H_c

4.077
4.069
4.061
4.054
4.046
4.039
4.034
4.027
4.019
4.011
4.003
3.996



Current Data Parameters
NAME KL33-NOESY-exp-processedA
EXPNO 2
PROCNO 1

F2 - Acquisition Parameters
Date_ 20130713
Time 17.13
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesypphpg
TD 2670
SOLVENT CDCl3
NS 8
DS 32
SWH 8012.820 Hz
FIDRES 3.001056 Hz
AQ 0.1666080 sec
RG 203
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
d0 -0.00001910 sec
D1 2.00000000 sec
D8 0.69999999 sec
d11 0.03000000 sec
d12 0.00002000 sec
D16 0.00020000 sec
In0 0 sec
STICNT 128
TAU 0.34880000 sec
d0orig -0.00001910 sec
philoop 0
t1loop 0
SFO1 400.1464009 MHz
NUC1 1H
P1 15.00 usec
p2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W
GPNAM[1] SMSQ10.100
GP21 40.00 %
P16 1000.00 usec

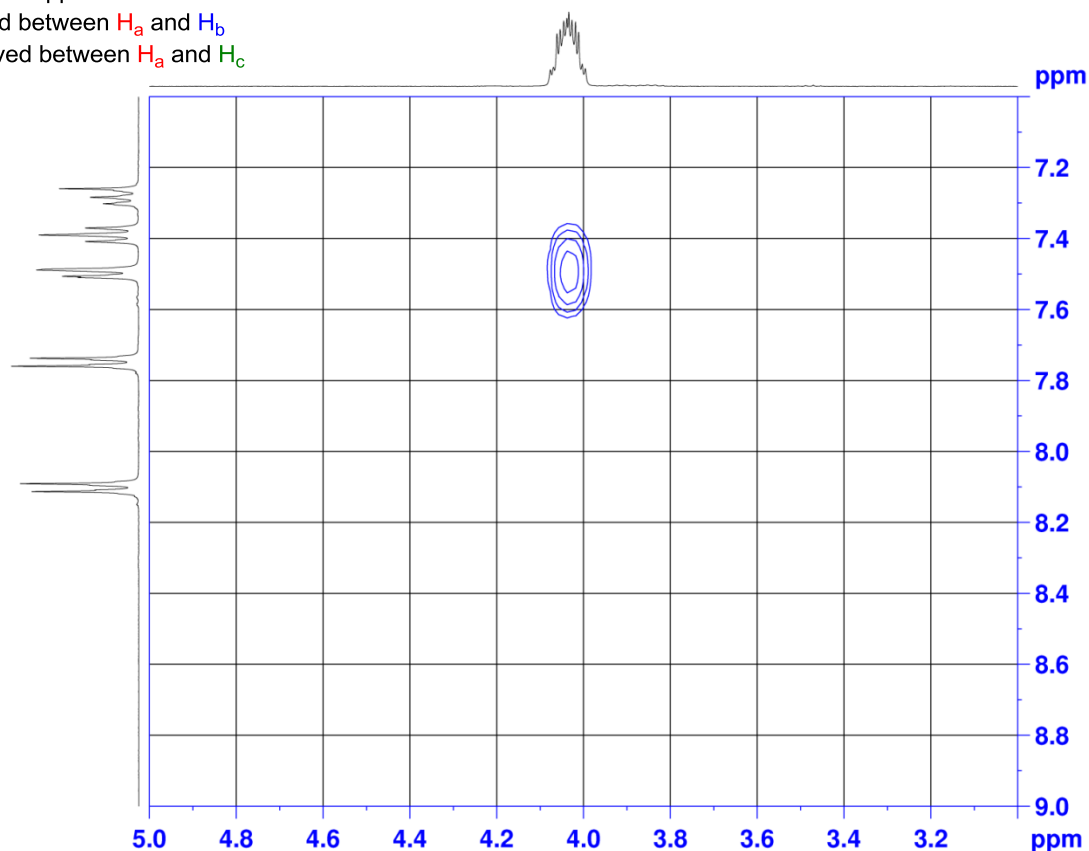
F1 - Acquisition parameters
TD 256
SFO1 400.1464 MHz
FIDRES 31.300001 Hz
SW 20.025 ppm
FhMODE States-TPPI

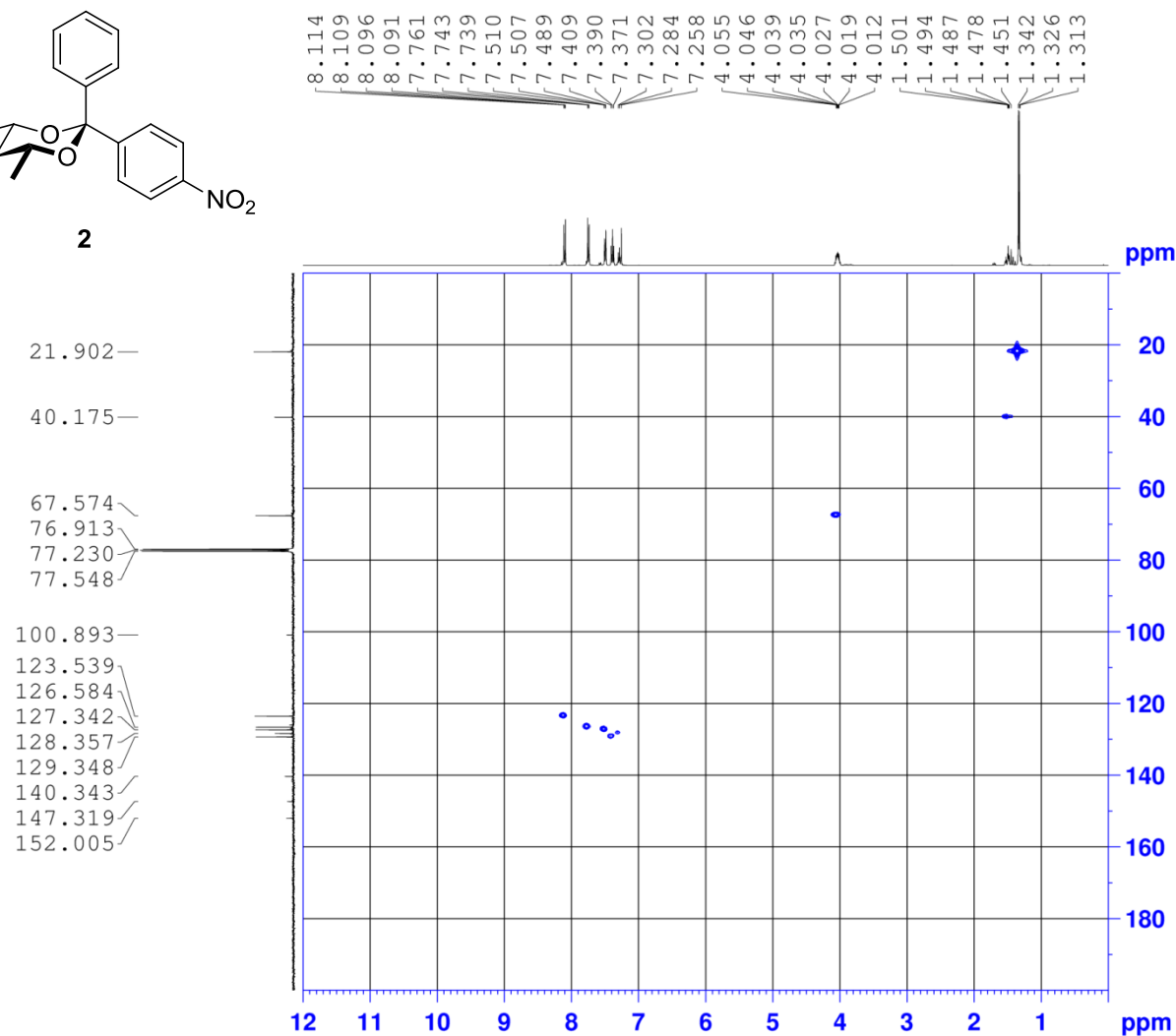
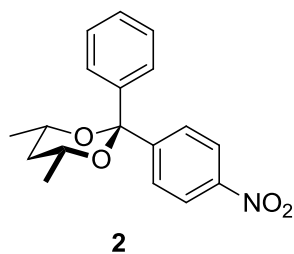
F2 - Processing parameters
SI 1024
SF 400.1440071 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440056 MHz
WDW USER
SSB 2
LB 0 Hz
GB 0

7.260
7.284
7.302
7.370
7.390
7.409
7.489
7.507
7.737
7.760

8.091
8.113





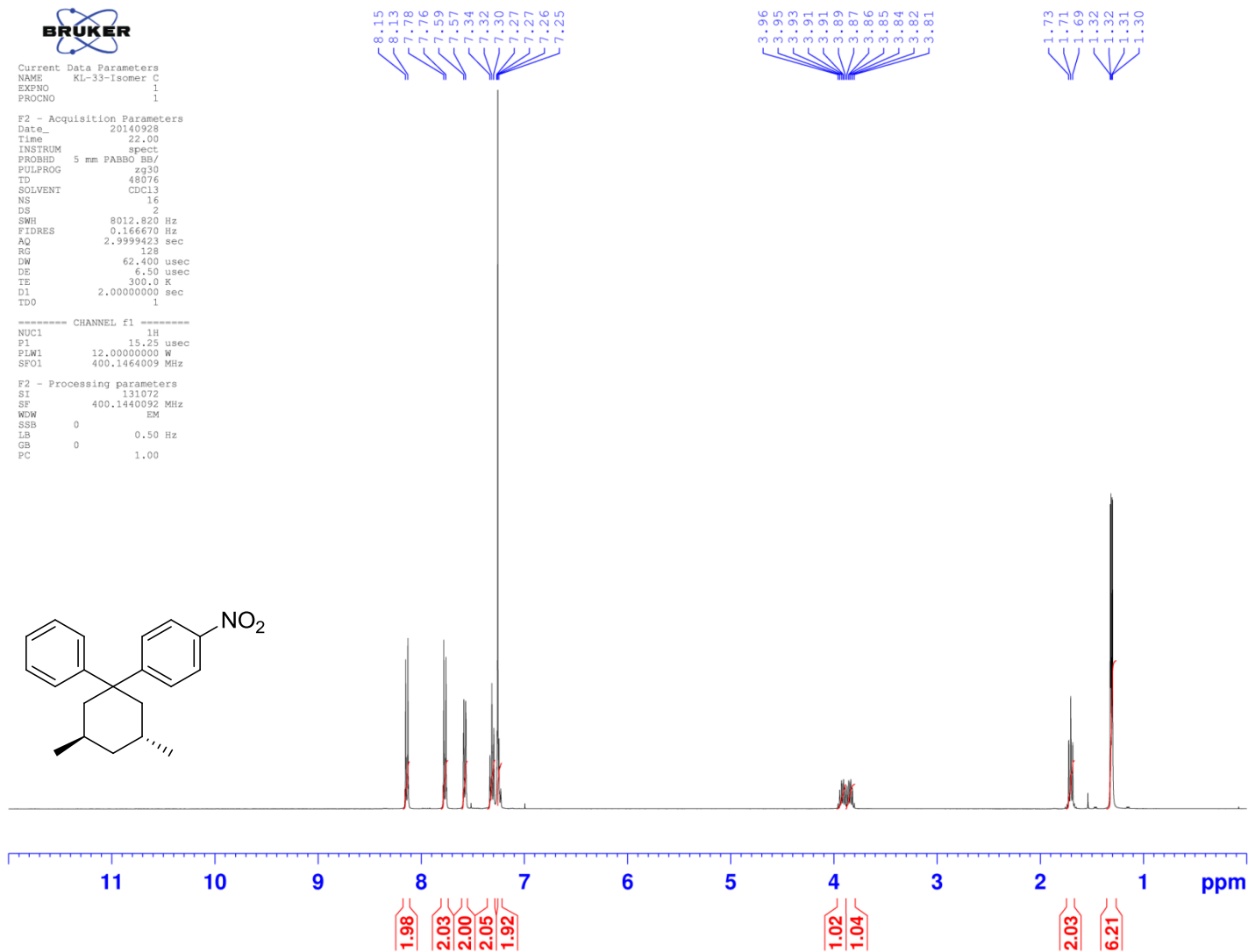
Current Data Parameters
 NAME NO2-Eq-Isomer-HSQC-proce
 EXPNO 1
 PROCNO 1

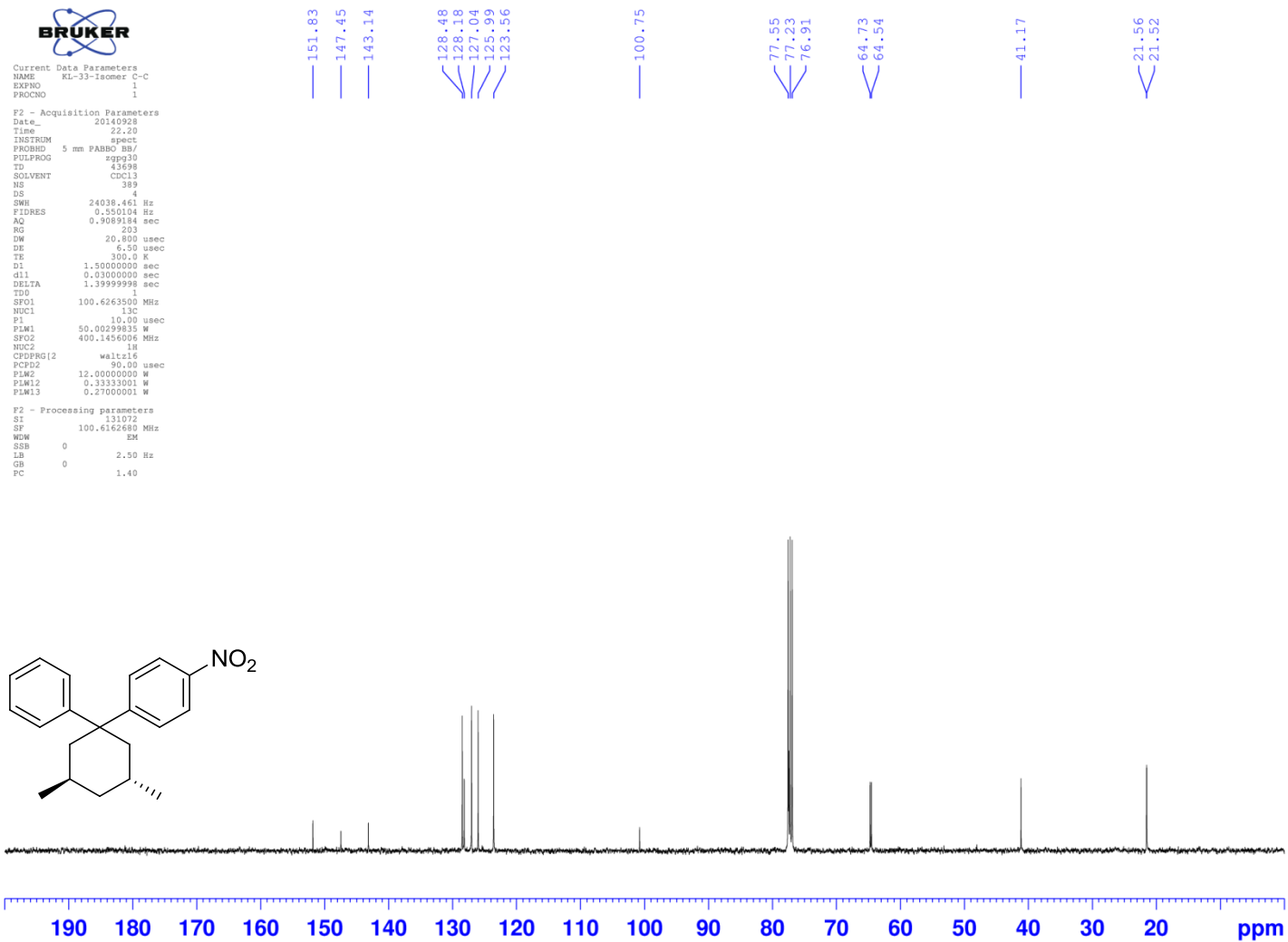
F2 - Acquisition Parameters
 Date_ 20131115
 Time 23.57
 INSTRUM spect
 PROBD 5 mm PASBO BB/
 PULPROG hsqcetgp
 TD 1024
 SOLVENT CDCl3
 NS 2
 DS 16
 SWH 5341.880 Hz
 FIDRES 5.216680 Hz
 AQ 0.8958464 sec
 RG 203
 DW 93.600 usec
 DE 6.50 usec
 TE 298.0 K
 CNST2 145.0000000
 d0 0.00000000 sec
 d1 1.50000000 sec
 d4 0.00172414 sec
 d11 0.03000000 sec
 d16 0.00020000 sec
 DELTA 0.00123600 sec
 DELTA1 0.00071919 sec
 in0 0 sec
 STICNT 128
 ZGPTNS
 d0orig 0.00000300 sec
 phloop 0
 t1loop 0
 SFO1 400.1464057 MHz
 NUC1 1H
 P1 15.00 usec
 P2 30.00 usec
 P28 1000.00 usec
 PLW1 12.00000000 W
 SFO2 100.6237933 MHz
 NUC2 13C
 CPDPRG2 garp
 P3 10.00 usec
 P4 20.00 usec
 PCPD2 80.00 usec
 PLW2 50.00000000 W
 PLW12 0.78125000 W
 GPNAM[1] SMSQ10.100
 GPNAM[2] SMSQ10.100
 GP21 80.00 %
 GP22 20.10 %
 P16 1000.00 usec

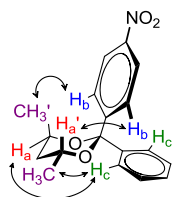
F1 - Acquisition parameters
 TD 256
 SFO1 100.6238 MHz
 FIDRES 65.106445 Hz
 SW 165.639 ppm
 FnmODE Echo-Antiecho

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSI
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.40

F1 - Processing parameters
 SI 1024
 MC2 echo-antiecho
 SF 100.6162890 MHz
 WDW USER
 SSB 2
 LB 0 Hz
 GB 0







H_a and H_a' = 3.81-3.96 ppm

H_b = 7.77 ppm

H_c = 7.58 ppm

CH_3 and CH_3' = 1.31 ppm

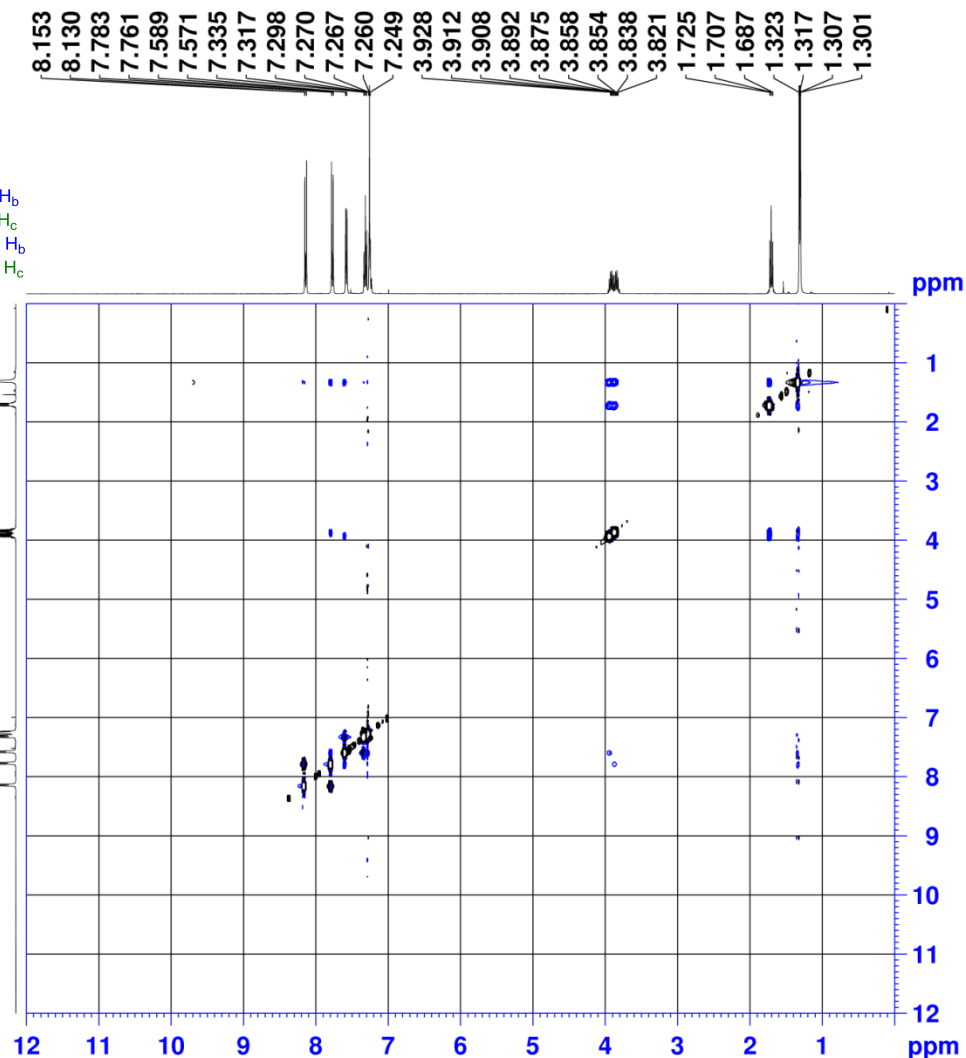
A NOE is observed between H_a' and H_b

A NOE is observed between H_a and H_c

A NOE is observed between CH_3' and H_b

A NOE is observed between CH_3 and H_c

1.301
1.307
1.317
1.323
1.687
1.707
1.725
3.838
3.858
3.908
3.928
7.249
7.260
7.267
7.270
7.298
7.317
7.335
7.571
7.589
7.761
7.783
8.130
8.153



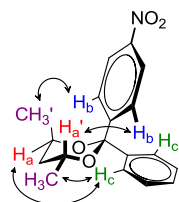
Current Data Parameters
NAME KL-33-Isomer HNOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20140928
Time 22.45
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesypphph
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506732 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
d0 -0.0001910 sec
D1 2.00000000 sec
D8 0.69999999 sec
d11 0.03000000 sec
d12 0.00020000 sec
D16 0.00020000 sec
In0 0 sec
STICNT 128
TAU 0.34880000 sec
d0orig -0.0001910 sec
philoop 0
tllloop 0
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
p2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FhMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440000 MHz
WDW USER
SSB 2
LB 0 Hz
GB 0



H_a and H_a' = 3.81-3.96 ppm
 H_b = 7.77 ppm
 H_c = 7.58 ppm
 CH_3 and CH_3' = 1.31 ppm
 A NOE is observed between H_a' and H_b
 A NOE is observed between H_a and H_c
 A NOE is observed between CH_3' and H_b
 A NOE is observed between CH_3 and H_c

3.961
 3.945
 3.928
 3.912
 3.908
 3.892
 3.875
 3.858
 3.854
 3.838
 3.821
 3.805



Current Data Parameters
 NAME KL-33-Isomer HNOESY
 EXPNO 1
 PROCNO 1

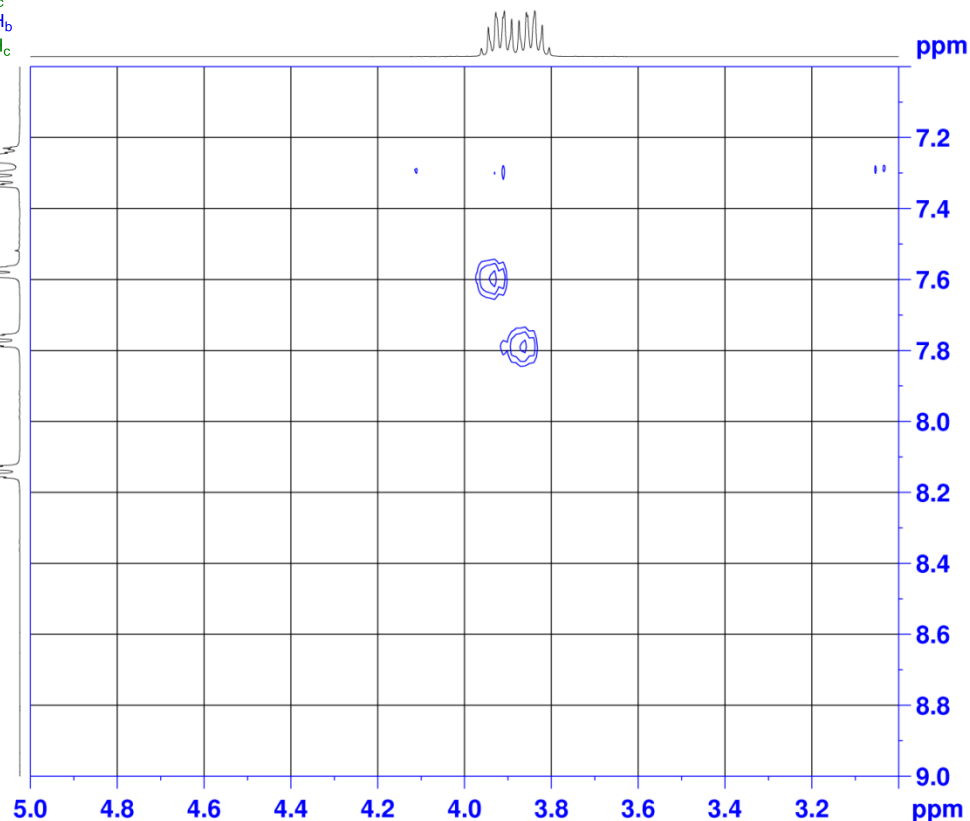
F2 - Acquisition Parameters
 Date_ 20140928
 Time 22.45
 INSTRUM spect
 PROBHD 5 mm PABBO BB/
 PULPROG noesypphph
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 32
 SWH 4084.967 Hz
 FIDRES 1.994613 Hz
 AQ 0.2506732 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 d0 -0.00001910 sec
 d1 2.00000000 sec
 d8 0.69999999 sec
 d11 0.03000000 sec
 d12 0.00002000 sec
 d16 0.00020000 sec
 In0 0 sec
 STICNT 128
 TAU 0.34880000 sec
 d0orig -0.00001910 sec
 phloop 0
 t1loop 0
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.00 usec
 p2 30.00 usec
 P17 2500.00 usec
 PLW1 12.00000000 W
 PLW10 3.99410009 W
 GPNAM[1] SMSQ10.100
 GP21 40.00 %
 P16 1000.00 usec

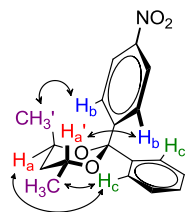
F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FhMODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440000 MHz
 WDW USER
 SSB 2
 LB 0 Hz
 GB 0

7.260
 7.267
 7.270
 7.298
 7.317
 7.335
 7.571
 7.589
 7.761
 7.783
 8.130
 8.153





H_a and H_a' = 3.81-3.96 ppm

H_b = 7.77 ppm

H_c = 7.58 ppm

CH_3 and CH_3' = 1.31 ppm

A NOE is observed between H_a' and H_b

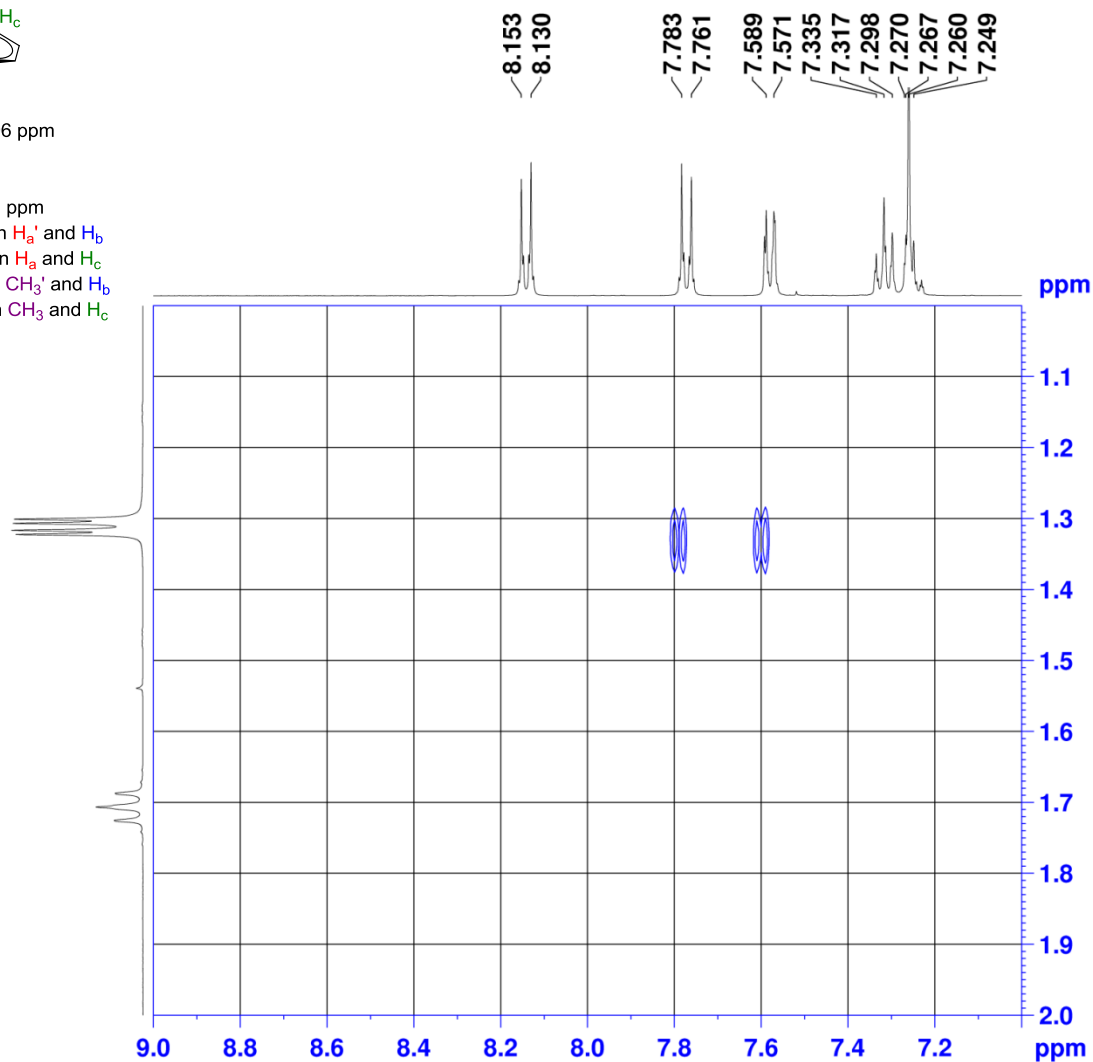
A NOE is observed between H_a and H_c

A NOE is observed between CH_3' and H_b

A NOE is observed between CH_3 and H_c

1.301
1.307
1.317
1.323

1.687
1.707
1.725



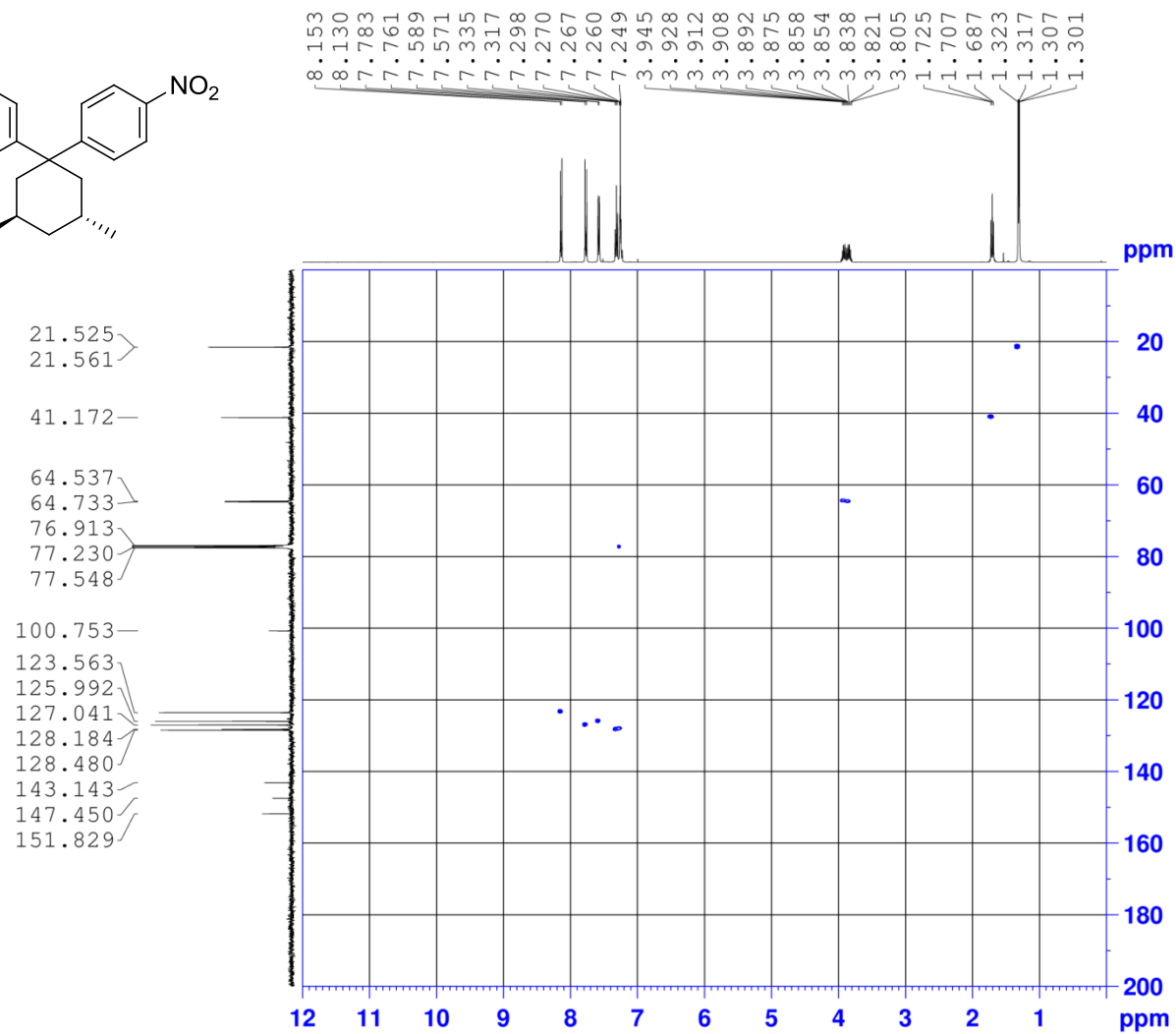
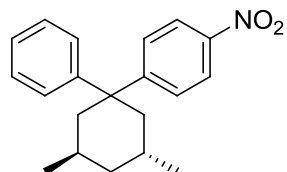
Current Data Parameters
NAME KL-33-Isomer HNOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20140928
Time 22.45
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesypphph
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506732 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
d0 -0.0001910 sec
D1 2.00000000 sec
D8 0.69999999 sec
d11 0.03000000 sec
d12 0.00020000 sec
D16 0.00020000 sec
In0 0 sec
STICNT 128
TAU 0.34880000 sec
d0orig -0.0001910 sec
philoop 0
t1loop 0
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
p2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FhMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440000 MHz
WDW USER
SSB 2
LB 0 Hz
GB 0



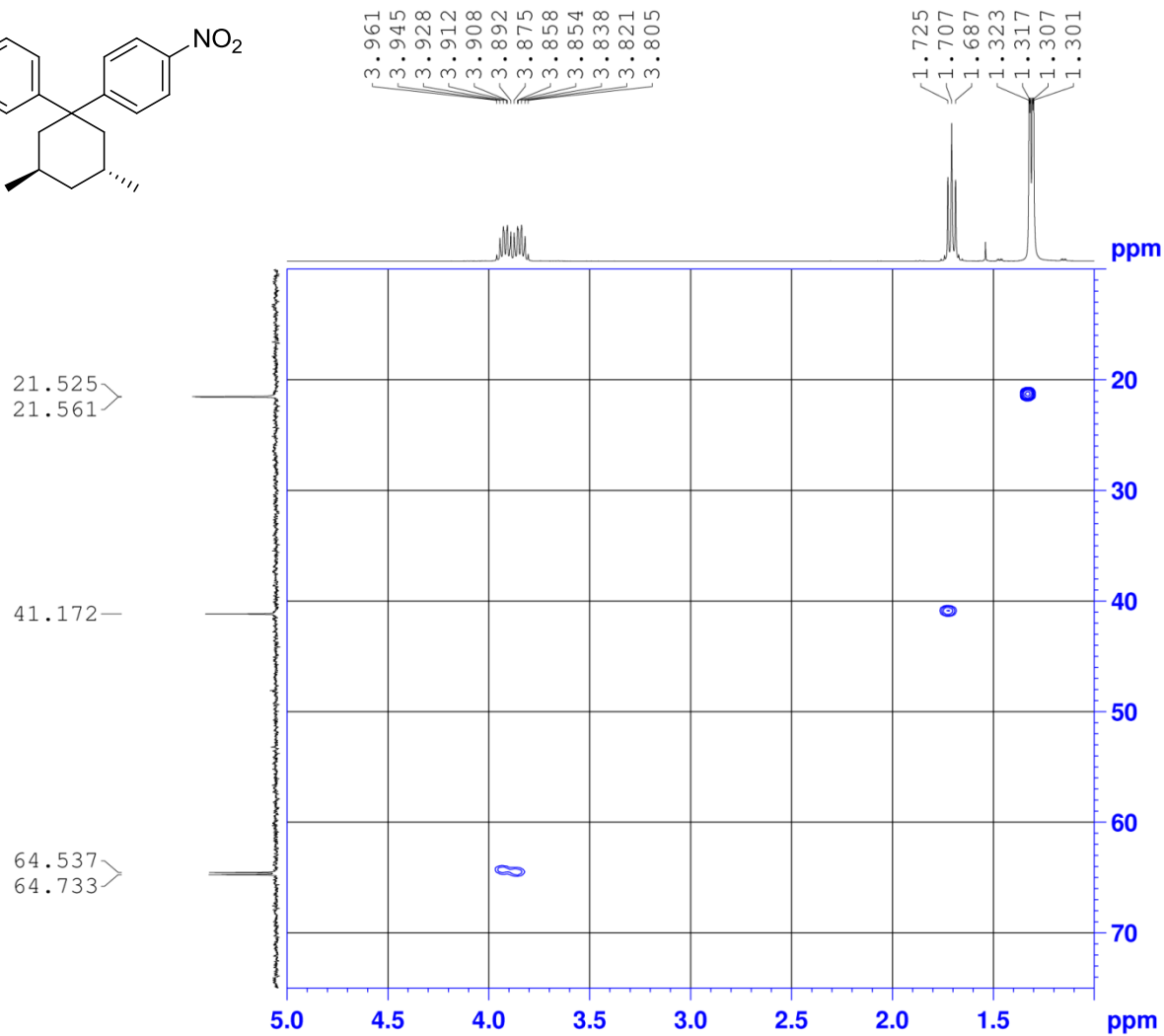
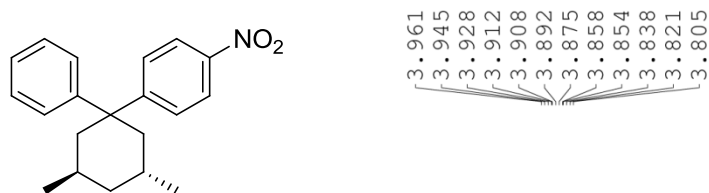
Current Data Parameters
NAME KL-33-Isomer HSQC
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20140928
Time 22.22
INSTRUM spect
PROBHD 5 mm PASPO BB/
PULPROG hsqcetgp
TD 1024
SOLVENT CDCl3
NS 2
DS 16
SWH 5341.880 Hz
FIDRES 5.216680 Hz
AQ 0.8958464 sec
RG 203
DW 93.600 usec
DE 6.50 usec
TE 300.0 K
CNST2 145.0000000
d0 0.0000000 sec
d1 1.5000000 sec
d4 0.00172414 sec
d11 0.03000000 sec
d16 0.00020000 sec
DELTA 0.00123600 sec
DELTA1 0.00071919 sec
in0 0 sec
STICNT 128
ZGPTNS
d0orig 0.00000000 sec
philoop 0
t1loop 0
SF01 400.1464057 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P28 1000.00 usec
PLW1 12.00000000 W
SF02 100.6237933 MHz
NUC2 13C
CPDPRG2 garp
P3 10.00 usec
P4 20.00 usec
PCPD2 80.00 usec
PLW2 50.00000000 W
PLW12 0.78125000 W
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GP1 80.00 %
GP2 20.10 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SF01 100.6238 MHz
FIDRES 65.106445 Hz
SW 165.639 ppm
FnMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162890 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0



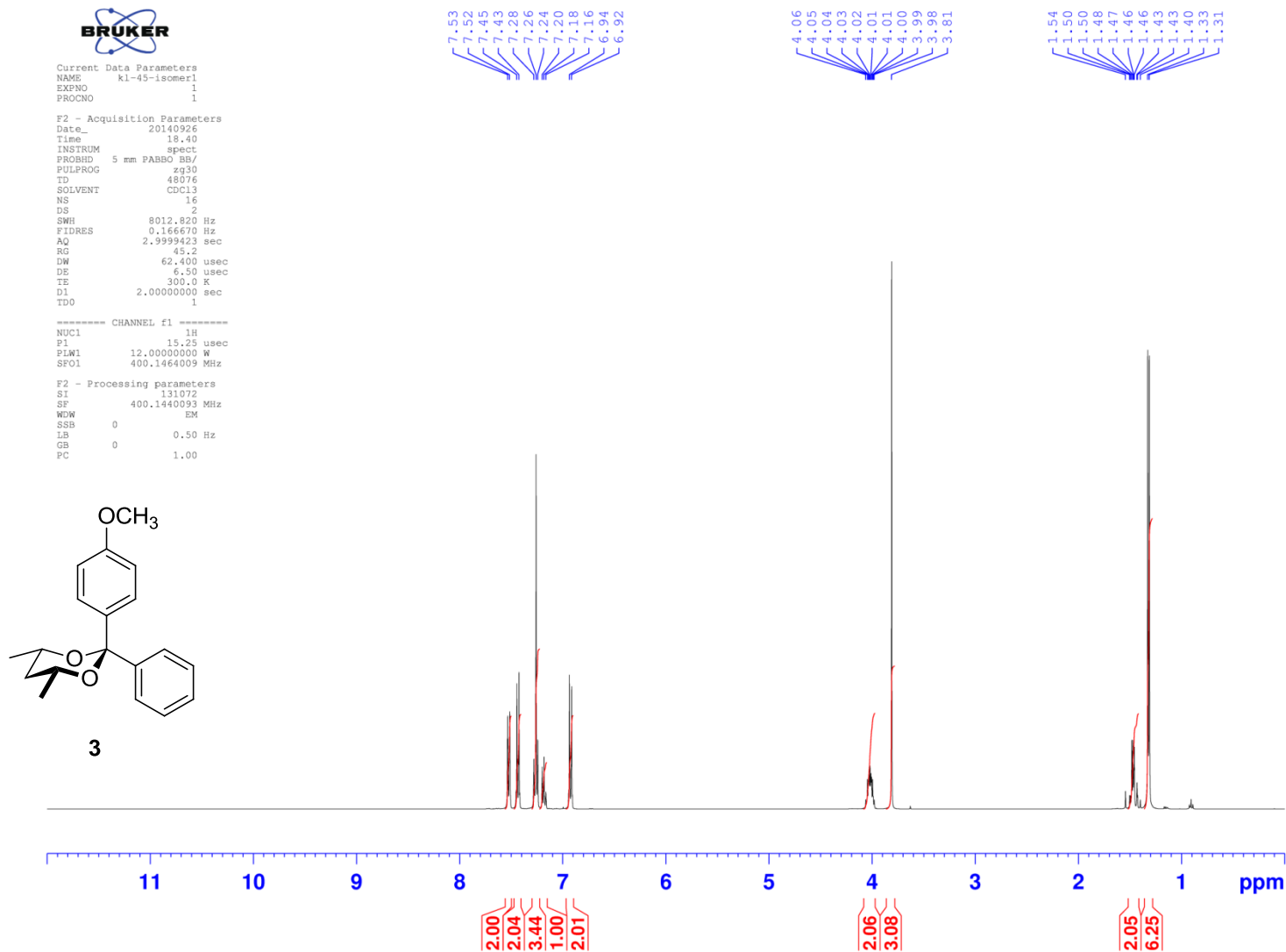
Current Data Parameters
NAME KL-33-Isomer HSQC
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20140928
Time 22.22
INSTRUM spect
PROBHD 5 mm PASPO BB/
PULPROG hsqcetgp
TD 1024
SOLVENT CDC13
NS 2
DS 16
SWH 5341.880 Hz
FIDRES 5.216680 Hz
AQ 0.8958464 sec
RG 203
DW 93.600 usec
DE 6.50 usec
TE 300.0 K
CNST2 145.0000000
d0 0.0000000 sec
d1 1.5000000 sec
d4 0.00172414 sec
d11 0.03000000 sec
d16 0.00020000 sec
DELTA 0.00123600 sec
DELTA1 0.00071919 sec
in0 0 sec
STICNT 128
ZGPTNS
d0orig 0.00000300 sec
philoop 0
t1loop 0
SF01 400.1464057 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P28 1000.00 usec
PLW1 12.00000000 W
SF02 100.6237933 MHz
NUC2 13C
CPDPRG2 garp
P3 10.00 usec
P4 20.00 usec
PCPD2 80.00 usec
PLW2 50.00000000 W
PLW12 0.78125000 W
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GP1 80.00 %
GP2 20.10 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SF01 100.6238 MHz
FIDRES 65.106445 Hz
SW 165.639 ppm
FnMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

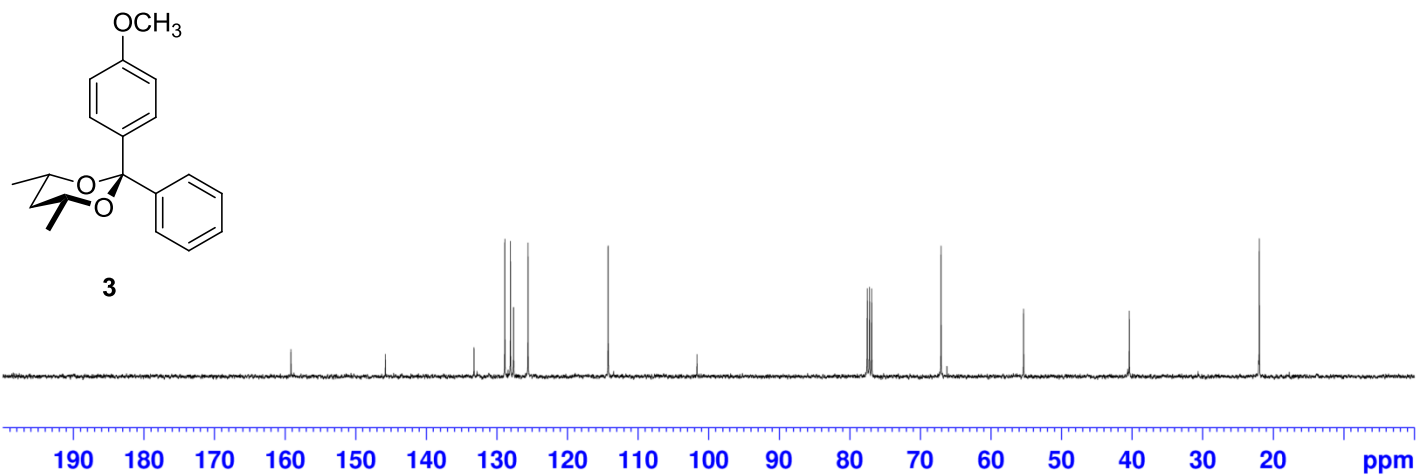
F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162890 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0

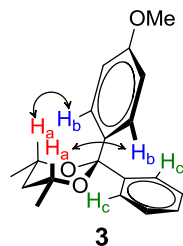




Current Data Parameters
NAME KL1-39-1-8C
EXPNO 2
PROCNO 1

F2 - Acquisition Parameters
Date_ 20130702
Time 11.17
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 45
DS 4
SWH 24038.461 Hz
FIDRES 0.550104 Hz
AQ 0.9089184 sec
RG 203
DW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
d11 0.03000000 sec
DELTA 1.39999998 sec
TD0 1
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLM12 0.33333001 W
PLM13 0.27000001 W
F2 - Processing parameters
SI 131072
SF 100.6162747 MHz
WDW EM
SSB 0
LB 2.50 Hz
GB 0
PC 1.40





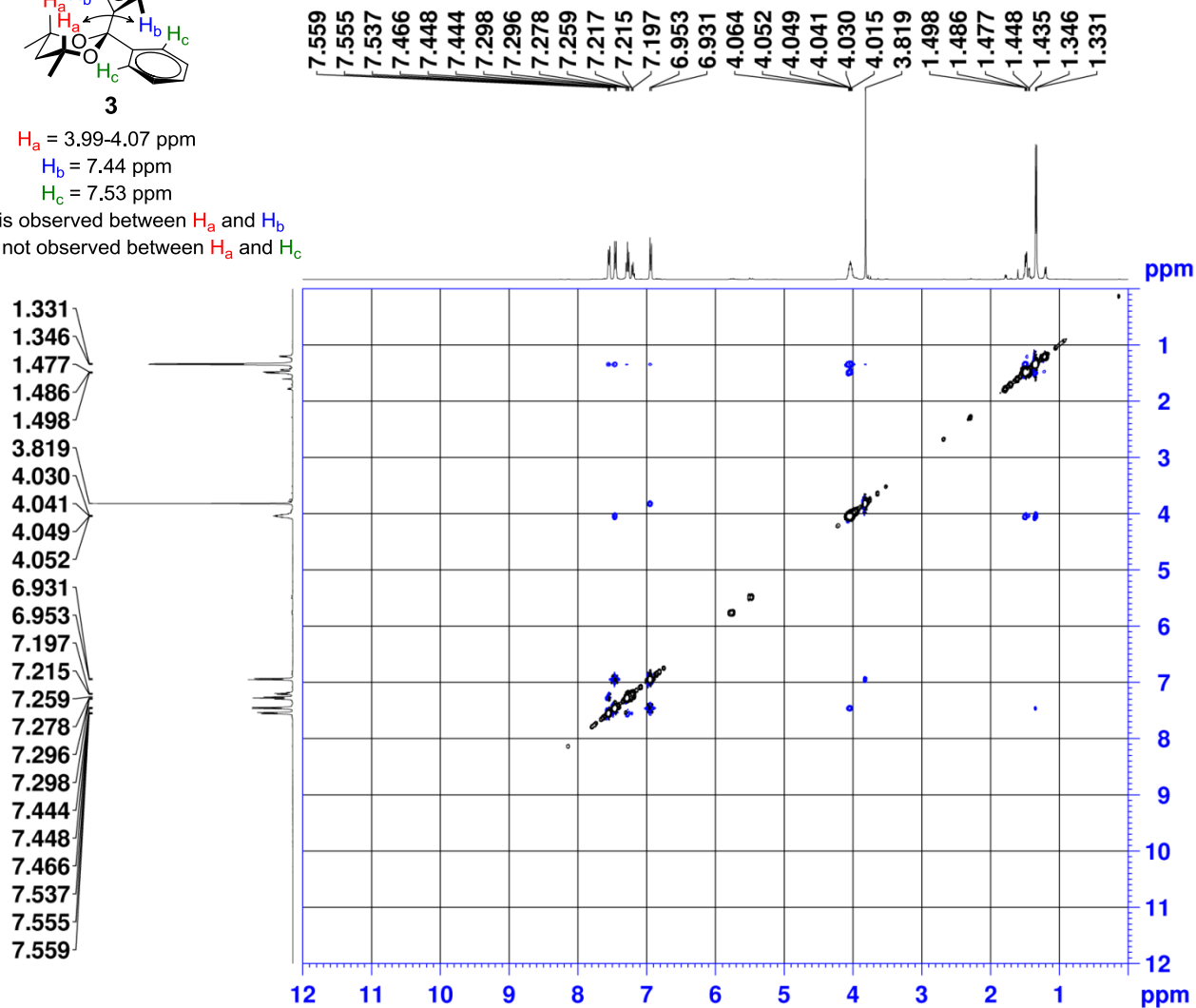
$H_a = 3.99\text{--}4.07\text{ ppm}$

$H_b = 7.44\text{ ppm}$

$H_c = 7.53\text{ ppm}$

A NOE is observed between H_a and H_b

A NOE is not observed between H_a and H_c



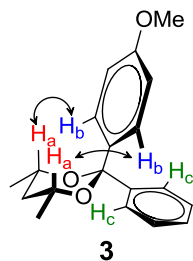
Current Data Parameters
NAME KL-1-45-NOESY-1 processed
EXPNO 2
PROCNO 1

F2 - Acquisition Parameters
Date_ 20130719
Time 1.25
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpph
TD 2670
SOLVENT CDCl3
NS 8
DS 32
SWH 8012.820 Hz
FIDRES 3.001056 Hz
AQ 0.1666080 sec
RG 28.5
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
d0 -0.00001910 sec
d1 2.00000000 sec
d8 0.40000001 sec
d11 0.03000000 sec
d12 0.00002000 sec
d16 0.00020000 sec
in0 0 sec
STICNT 128
TAU 0.19880000 sec
d0orig -0.00001910 sec
philoop 0
t1loop 0
SFO1 400.1464009 MHz
NUC1 1H
P1 15.00 usec
p2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 668
SFO1 400.1464 MHz
FIDRES 11.995211 Hz
SW 20.025 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440054 MHz
WDW QSI
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440053 MHz
WDW USER
SSB 2
LB 0 Hz
GB 0



H_a = 3.99-4.07 ppm

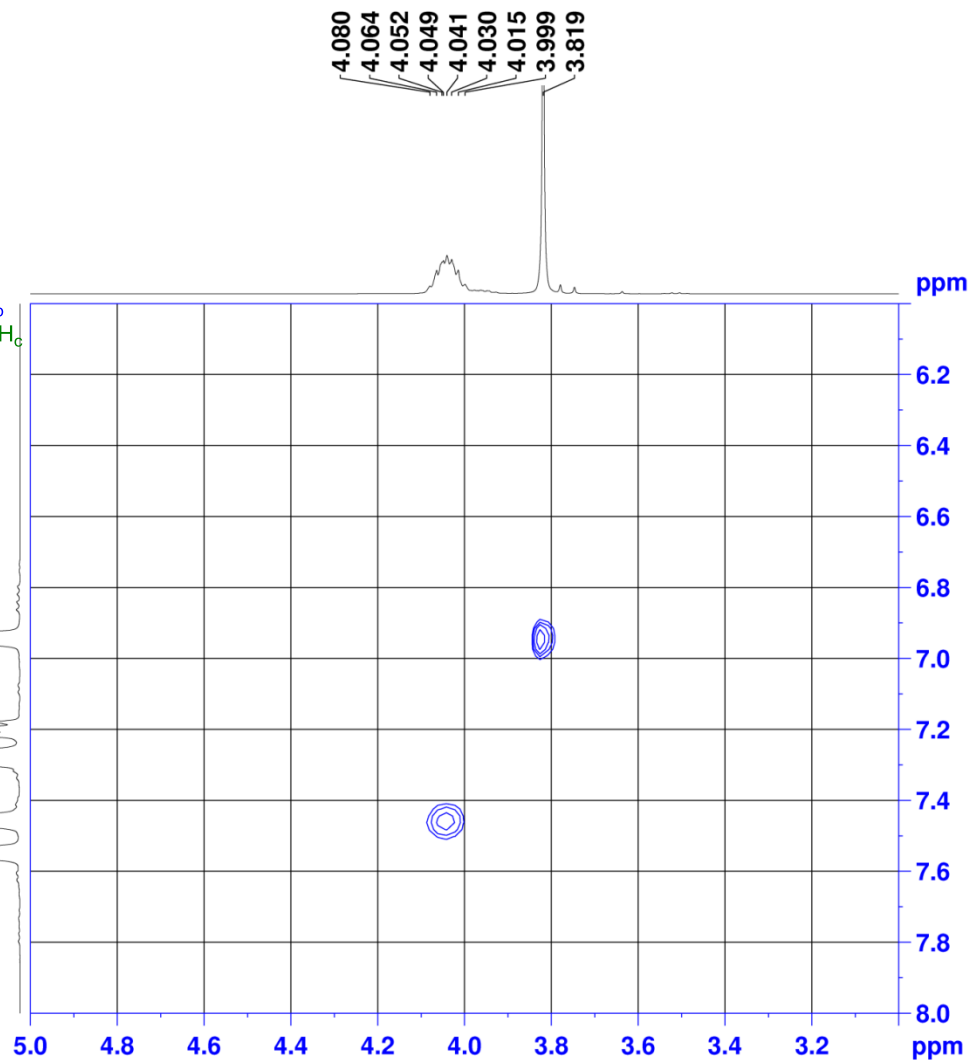
H_b = 7.44 ppm

H_c = 7.53 ppm

A NOE is observed between H_a and H_b

A NOE is not observed between H_a and H_c

6.931
6.953
7.178
7.181
7.197
7.215
7.217
7.259
7.278
7.296
7.298
7.444
7.448
7.466
7.537
7.555
7.559



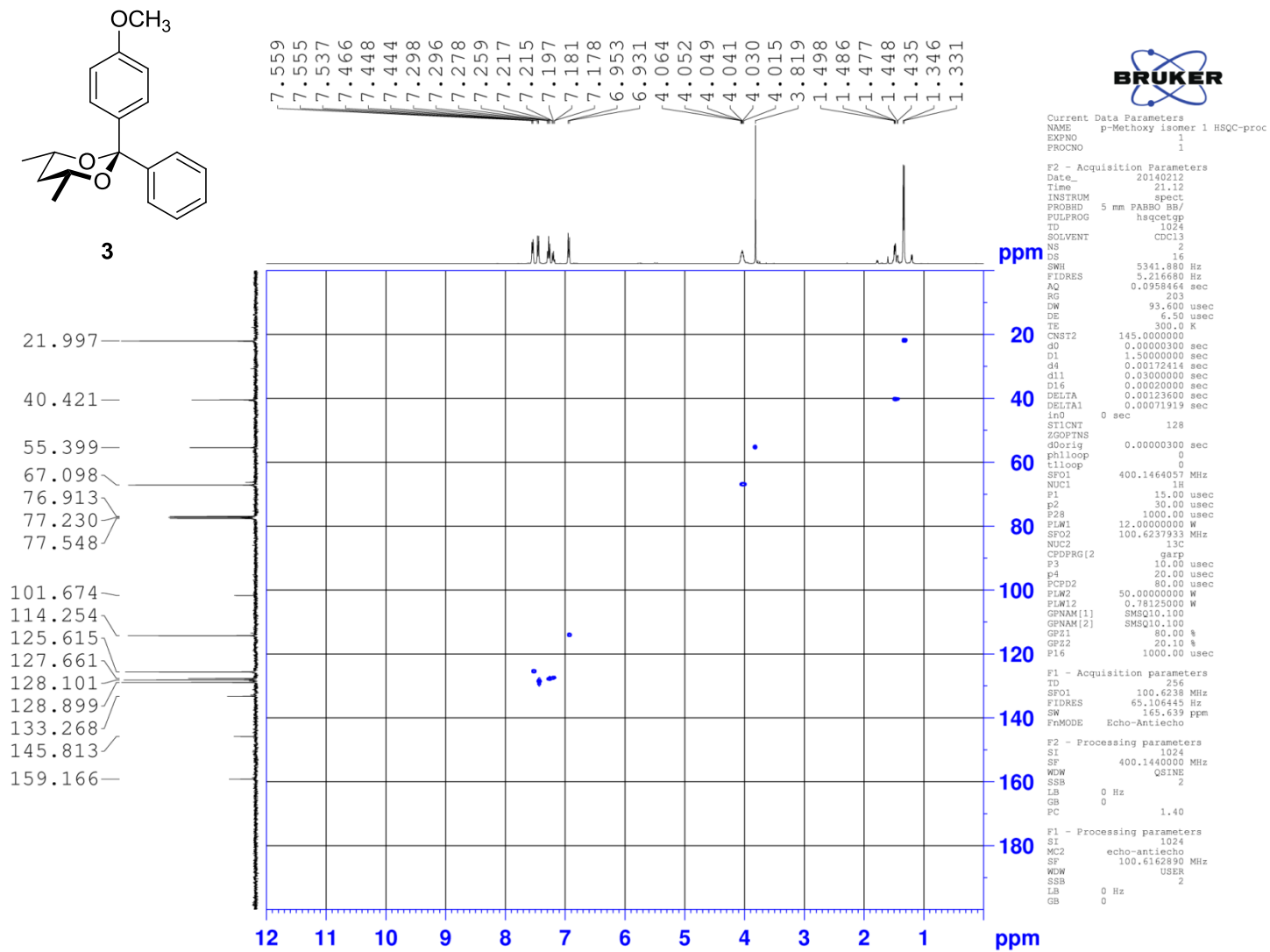
Current Data Parameters
NAME KL-1-45-NOESY-1 processed
EXPNO 2
PROCNO 1

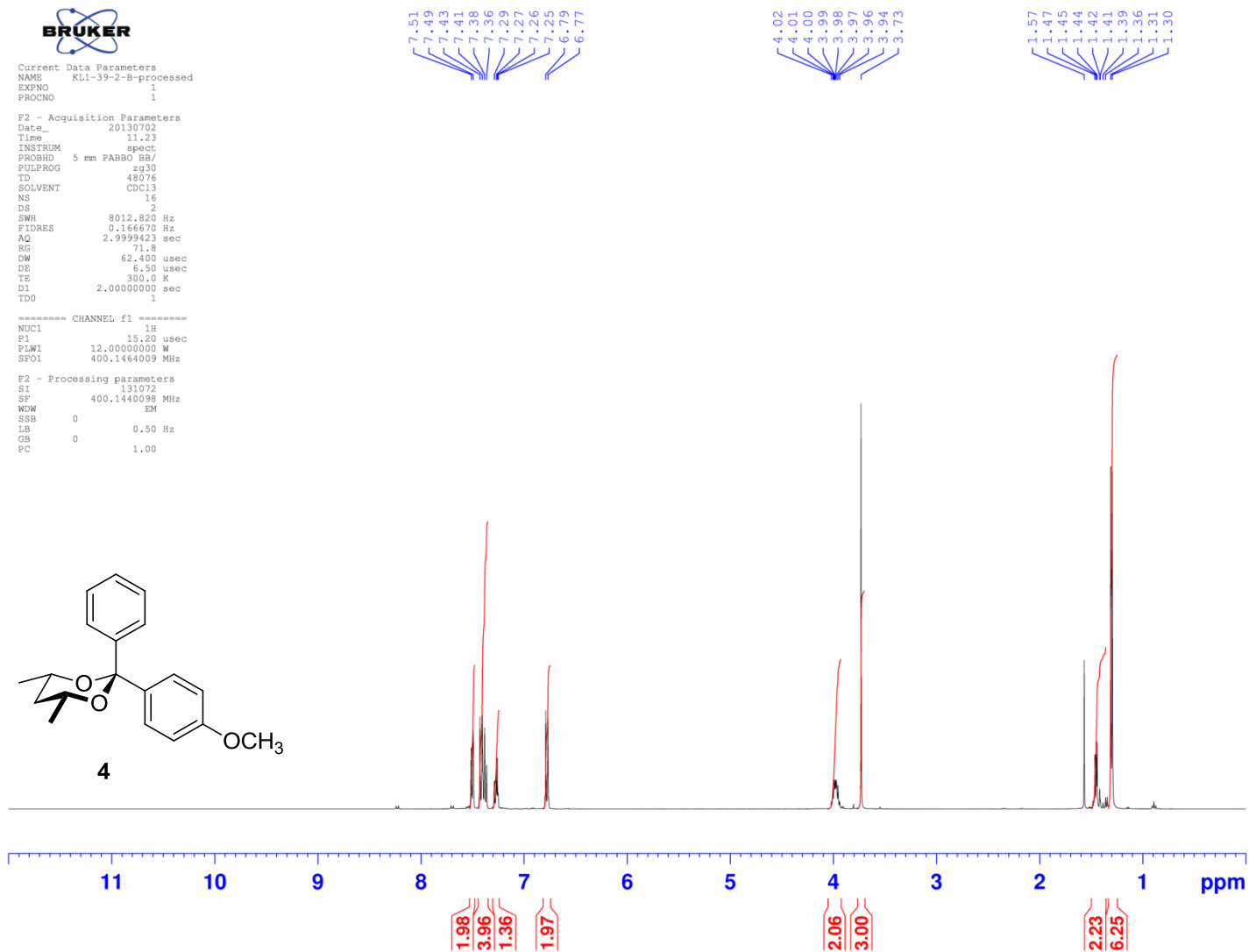
F2 - Acquisition Parameters
Date_ 20130719
Time 1.25
INSTRUM spect
PROBHD 5 mm FASBO BB/
PULPROG noesygpph
TD 2670
SOLVENT CDCl3
NS 8
DS 32
SWH 8012.820 Hz
FIDRES 3.001056 Hz
AQ 0.1666080 sec
RG 28.5
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
d0 -0.00001910 sec
d1 2.00000000 sec
d8 0.40000001 sec
d11 0.03000000 sec
d12 0.00002000 sec
d16 0.00020000 sec
in0 0 sec
STICNT 128
TAU 0.19880000 sec
d0orig -0.00001910 sec
philoop 0
tloop 0
SFO1 400.1464009 MHz
NUC1 1H
P1 15.00 usec
p2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 668
SFO1 400.1464 MHz
FIDRES 11.995211 Hz
SW 20.025 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440054 MHz
WDW QSI
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440053 MHz
WDW USER
SSB 2
LB 0 Hz
GB 0



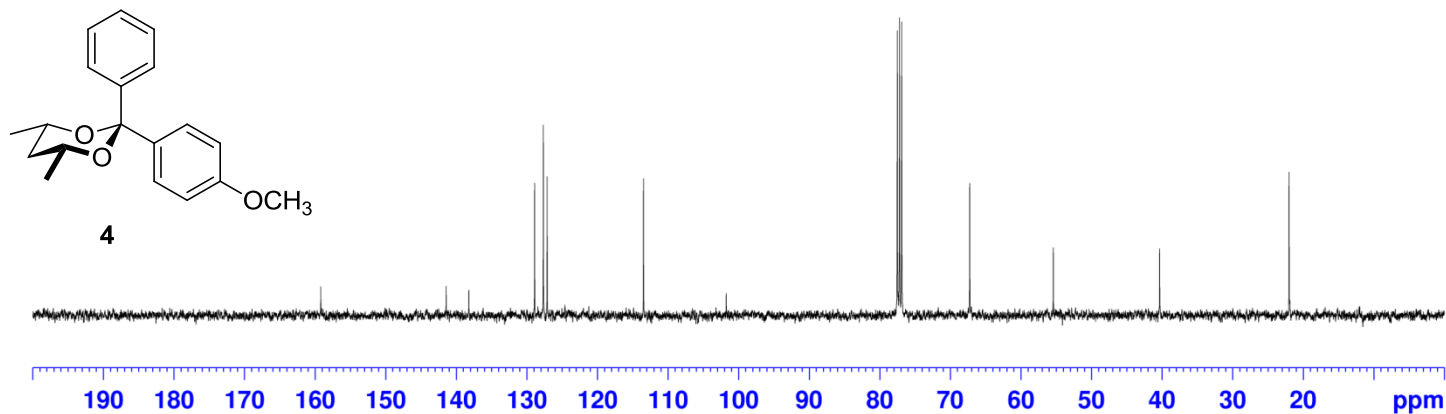


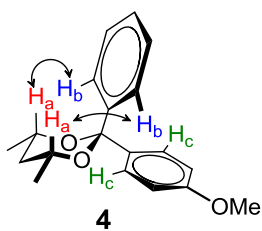
BRUKER

Current Data Parameters
 NAME KL1-39-2-DC
 EXPNO 2
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20130702
 Time_ 11.27
 INSTRUM spect
 PROBHD 5 mm PABBO BB/
 PULPROG zgpg30
 TD 43698
 SOLVENT CDCl3
 NS 71
 DS 4
 SWH 24038.461 Hz
 FIDRES 0.550104 Hz
 AQ 0.9089184 sec
 RG 203
 DW 20.800 usec
 DE 6.50 usec
 TE 300.0 K
 D1 1.50000000 sec
 d11 0.03000000 sec
 DELTA 1.39999998 sec
 TDD 1
 SFO1 100.6263500 MHz
 NUC1 13C
 P1 10.00 usec
 PL1 50.00299835 W
 SFO2 400.1456006 MHz
 NUC2 1H
 CPDPRG2 waltz16
 PCPD2 90.00 usec
 PLW2 12.00000000 W
 PLW12 0.33333001 W
 PLW13 0.27000001 W

F2 - Processing parameters
 SI 131072
 SF 100.6162694 MHz
 WDW EM
 SSB 0
 LB 2.50 Hz
 GB 0
 PC 1.40





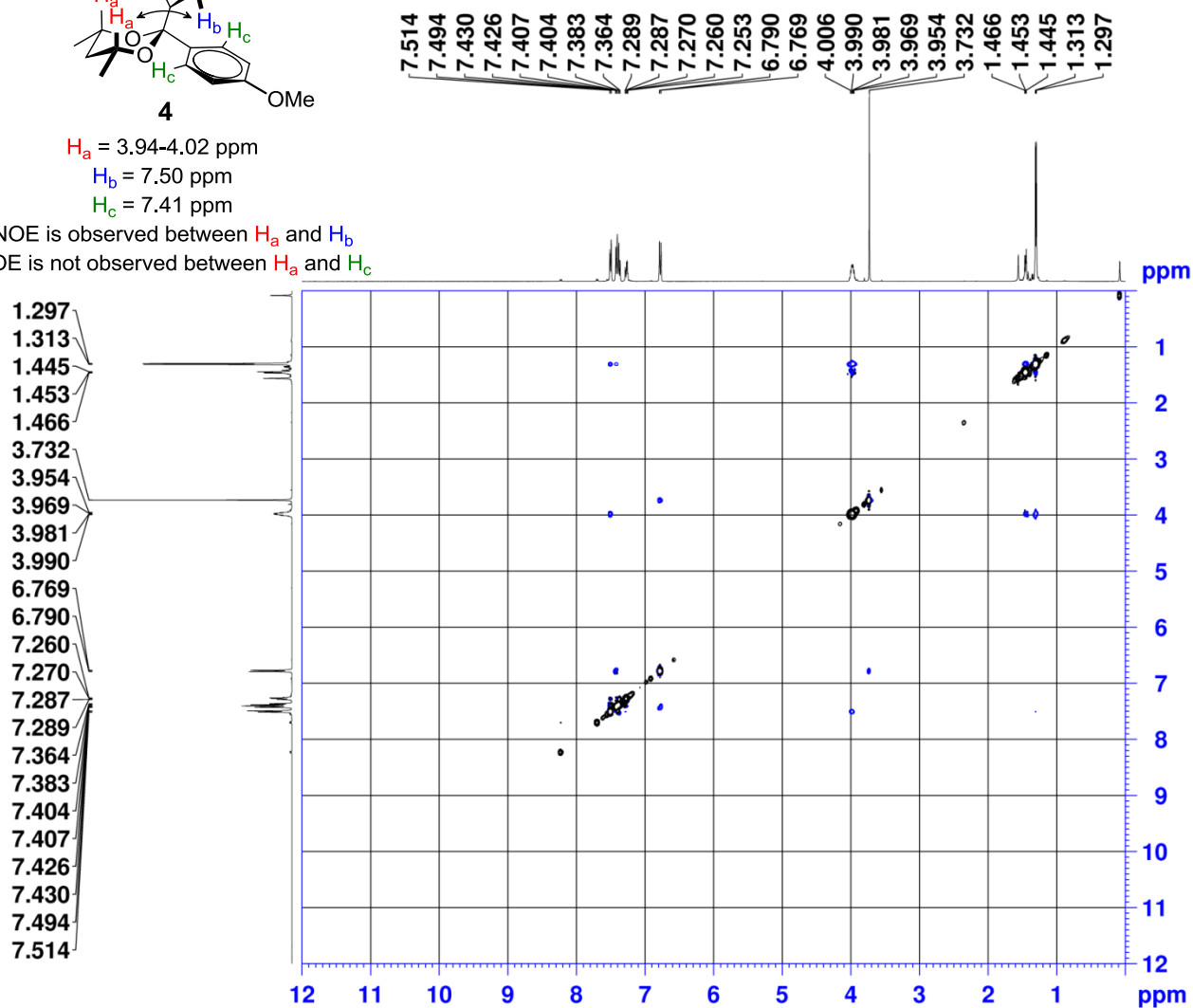
H_a = 3.94-4.02 ppm

H_b = 7.50 ppm

H_c = 7.41 ppm

A NOE is observed between H_a and H_b

A NOE is not observed between H_a and H_c



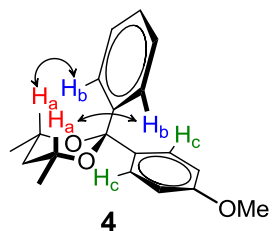
Current Data Parameters
NAME KL-1-45-NOESY-2-processed c
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20130718
Time 20.41
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpgppp
TD 2670
SOLVENT CDCl3
NS 8
DS 32
SWH 8012.820 Hz
FIDRES 3.001056 Hz
AQ 0.1666080 sec
RG 80.6
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
d0 -0.00001842 sec
D1 2.00000000 sec
D8 0.44999999 sec
d11 0.03000000 sec
d12 0.00020000 sec
D16 0.00020000 sec
In0 0 sec
STICNT 128
TAU 0.22379999 sec
d0orig -0.00001842 sec
philoop 0
t1loop 0
SFO1 400.1464009 MHz
NUC1 1H
P1 14.47 usec
p2 28.94 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.71679997 W
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 668
SFO1 400.1464 MHz
FIDRES 11.995227 Hz
SW 20.025 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440057 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440058 MHz
WDW USER
SSB 2
LB 0 Hz
GB 0



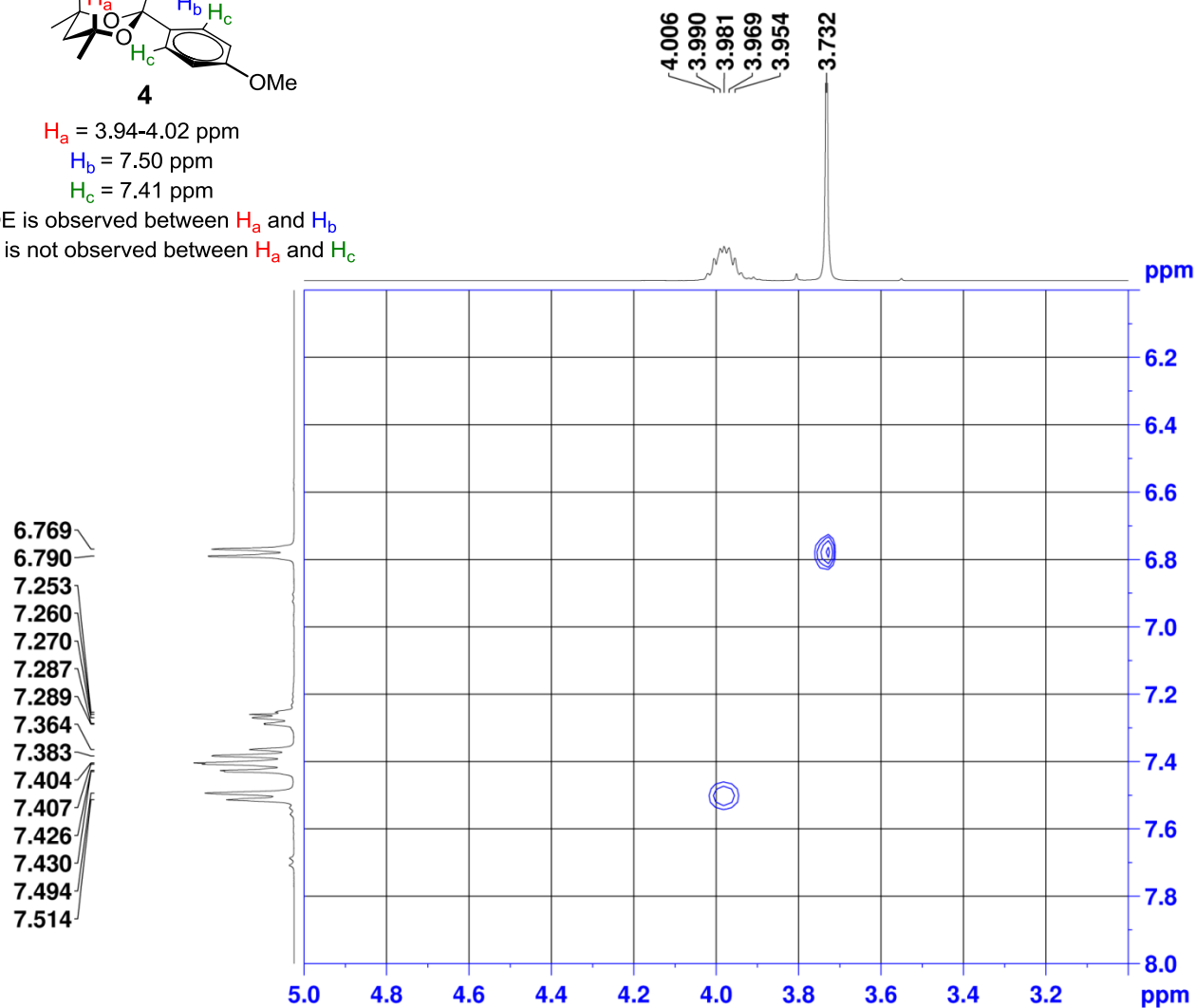
$H_a = 3.94\text{--}4.02\text{ ppm}$

$H_b = 7.50\text{ ppm}$

$H_c = 7.41\text{ ppm}$

A NOE is observed between H_a and H_b

A NOE is not observed between H_a and H_c



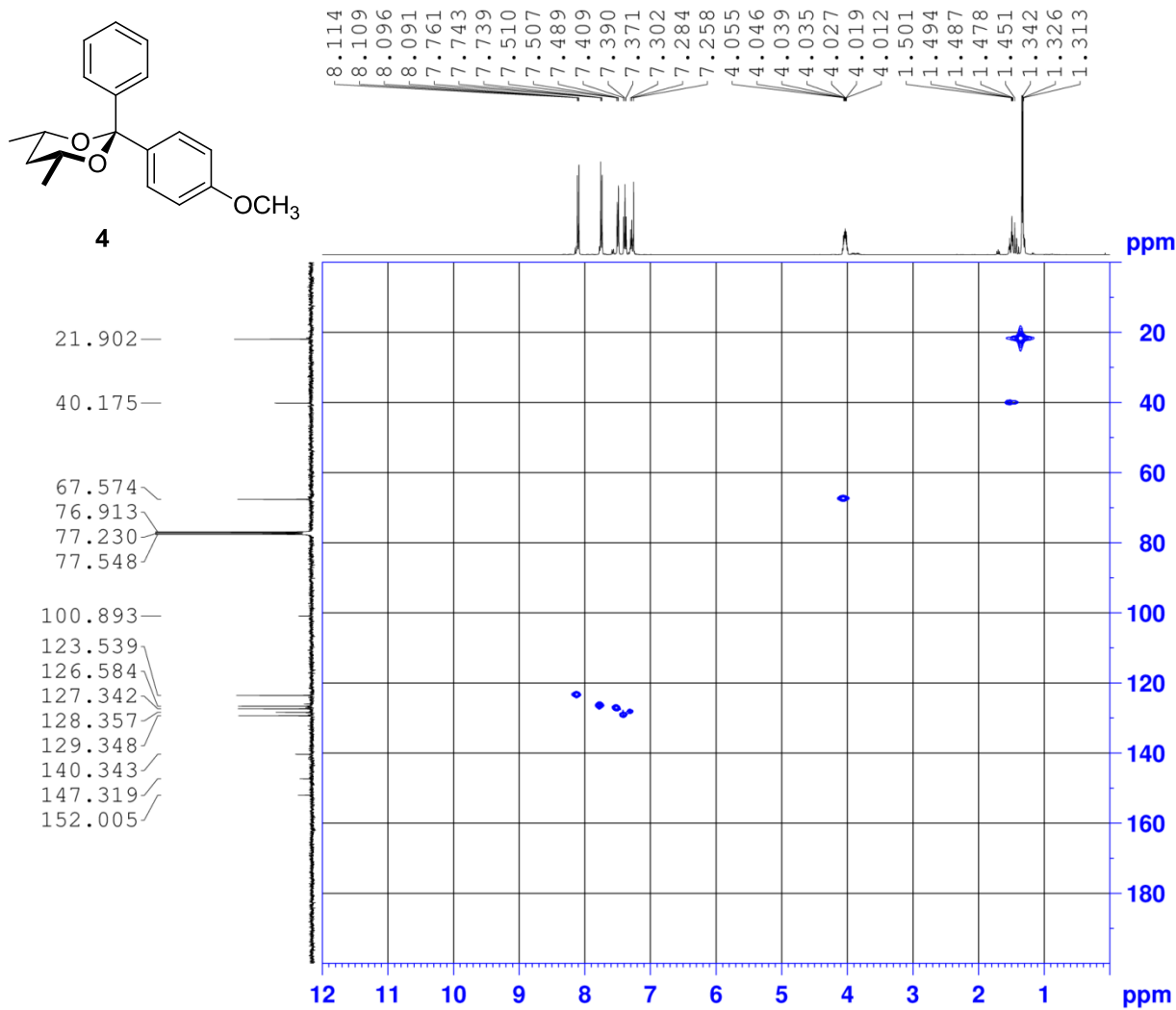
Current Data Parameters
NAME KL-1-45-NOESY-2-processed c
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20130718
Time 20.41
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpgppp
TD 2670
SOLVENT CDCl3
NS 8
DS 32
SWH 8012.820 Hz
FIDRES 3.001056 Hz
AQ 0.1666080 sec
RG 80.6
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
d0 -0.00001842 sec
D1 2.00000000 sec
D8 0.44999999 sec
d11 0.03000000 sec
d12 0.00002000 sec
D16 0.00020000 sec
Ino 0 sec
STICNT 128
TAU 0.22379999 sec
d0orig -0.00001842 sec
philoop 0
t1loop 0
SFO1 400.1464009 MHz
NUC1 1H
P1 14.47 usec
p2 28.94 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.71679997 W
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 668
SFO1 400.1464 MHz
FIDRES 11.995227 Hz
SW 20.025 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440057 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440058 MHz
WDW USRA
SSB 2
LB 0 Hz
GB 0



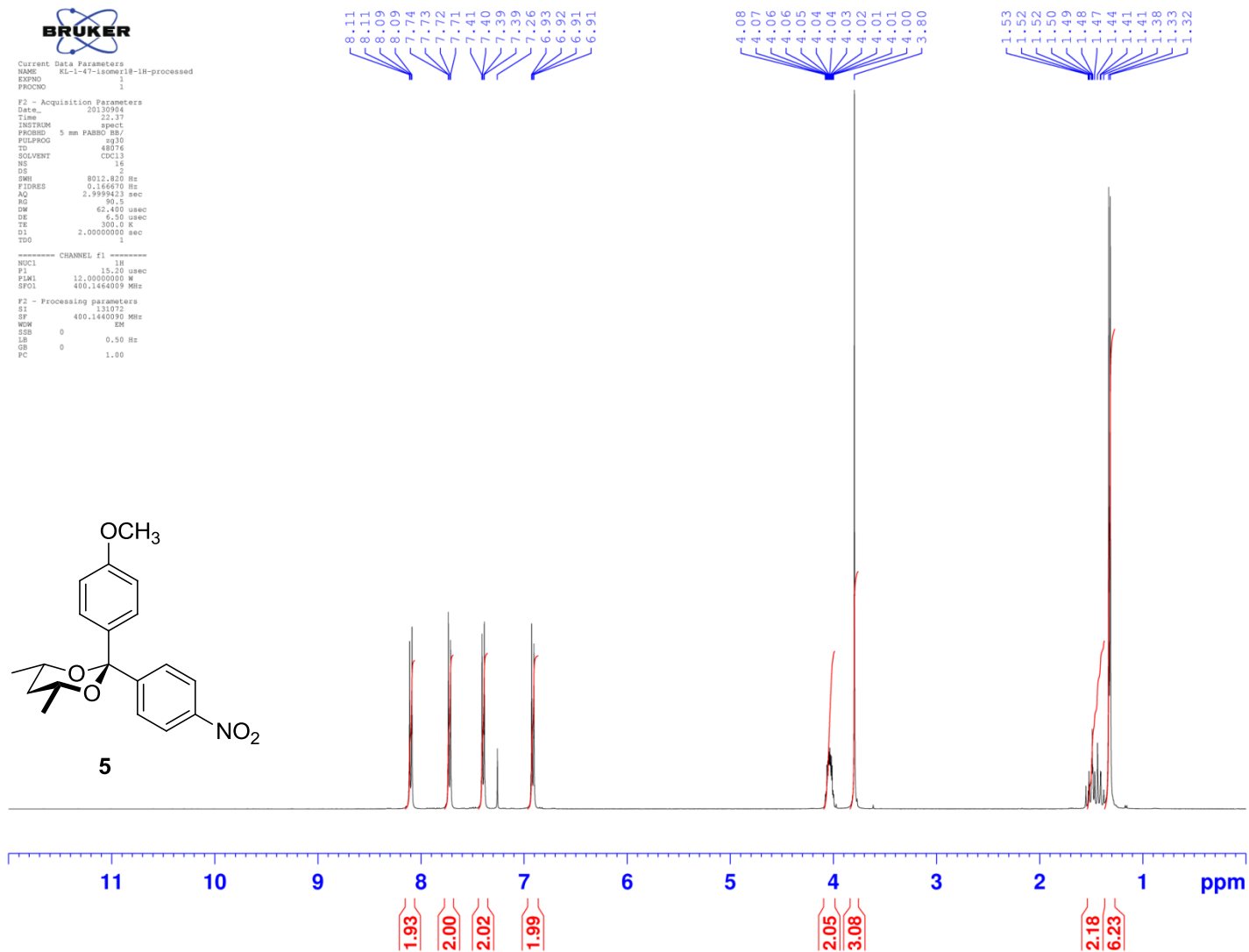
Current Data Parameters
 NAME NO2-Eq-Isomer-HSQC-proce
 EXPNO 1
 PROCNO 1


F2 - Acquisition Parameters
 Date_ 20131115
 Time 23.57
 INSTRUM spect
 PROBD 5 mm PASBO BB/
 PULPROG hsqcetgp
 TD 1024
 SOLVENT CDCl3
 NS 2
 DS 16
 SWH 5341.880 Hz
 FIDRES 5.216680 Hz
 AQ 0.8958464 sec
 RG 203
 DW 93.600 usec
 DE 6.50 usec
 TE 298.0 K
 CNST2 145.0000000
 d0 0.00000000 sec
 d1 1.50000000 sec
 d4 0.00172414 sec
 d11 0.03000000 sec
 d16 0.00020000 sec
 DELTA 0.00123600 sec
 DELTA1 0.00071919 sec
 in0 0 sec
 STICNT 128
 ZGPTNS
 d0orig 0.00000300 sec
 phloop 0
 t1loop 0
 SFO1 400.1464057 MHz
 NUC1 1H
 P1 15.00 usec
 P2 30.00 usec
 P28 1000.00 usec
 PLW1 12.00000000 W
 SFO2 100.6237933 MHz
 NUC2 13C
 CPDPRG2 garp
 P3 10.00 usec
 P4 20.00 usec
 PCPD2 80.00 usec
 PLW2 50.00000000 W
 PLW12 0.78125000 W
 GPNAM[1] SMSQ10.100
 GPNAM[2] SMSQ10.100
 GPZ1 80.00 %
 GPZ2 20.10 %
 P16 1000.00 usec

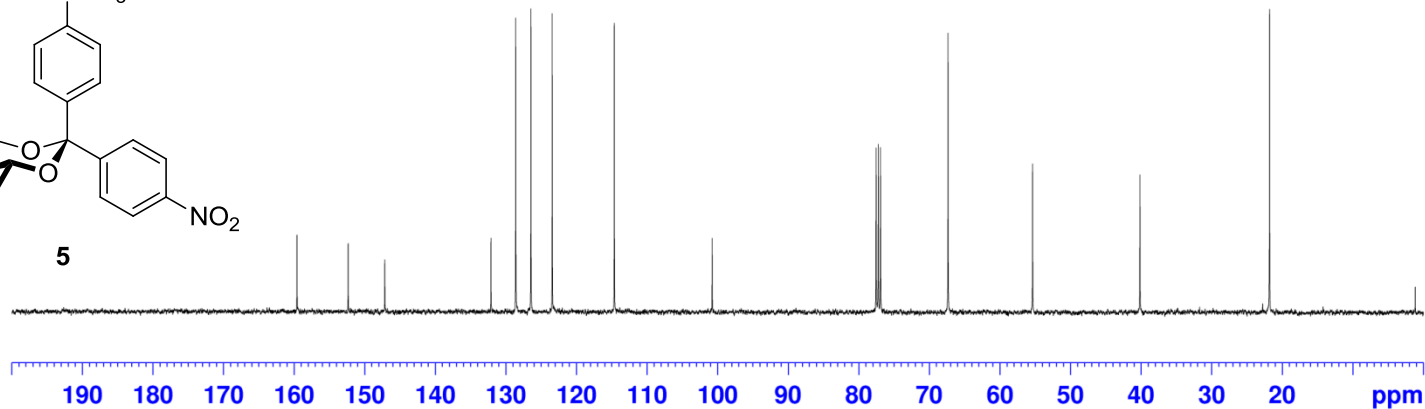
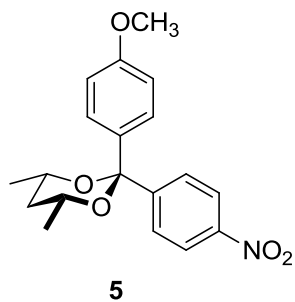
F1 - Acquisition parameters
 TD 256
 SFO1 100.6238 MHz
 FIDRES 65.106445 Hz
 SW 165.639 ppm
 FnmODE Echo-Antiecho

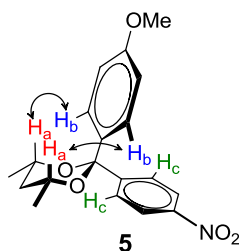
F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.40

F1 - Processing parameters
 SI 1024
 MC2 echo-antiecho
 SF 100.6162890 MHz
 WDW TRAP
 SSB 2
 LB 0 Hz
 GB 0




 Current Data Parameters
 NAME K2-1-47-isomer1-C-processed
 EXPNO 2
 PROCNO 1
 F2 - Acquisition Parameters
 Date_ 20130823
 Time 1.33
 INSTRUM spect
 PROBHD 5 mm PABBO BB/
 PULPROG zgpg30
 TD 65536
 SOLVENT CDCl3
 NS 63
 DS 4
 SWH 24038.461 Hz
 FIDRES 0.550104 Hz
 AQ 0.9089184 sec
 RG 203
 DW 20.800 usec
 DE 6.50 usec
 TE 300.0 K
 D1 1.50000000 sec
 d11 0.03000000 sec
 DELTA 1.39999998 sec
 TD0 1
 SFO1 100.6263500 MHz
 NUC1 13C
 P1 10.00 usec
 PLW1 50.00299835 W
 SFO2 400.1456006 MHz
 NUC2 1H
 CTDPRG12 wait16
 PCPD2 90.00 usec
 PLW2 12.00000000 W
 PLW12 0.33333001 W
 PLW13 0.27000001 W
 F2 - Processing parameters
 SI 131072
 SF 100.6162770 MHz
 WDW EM
 SSB 0
 LB 2.50 Hz
 GB 0
 PC 1.40





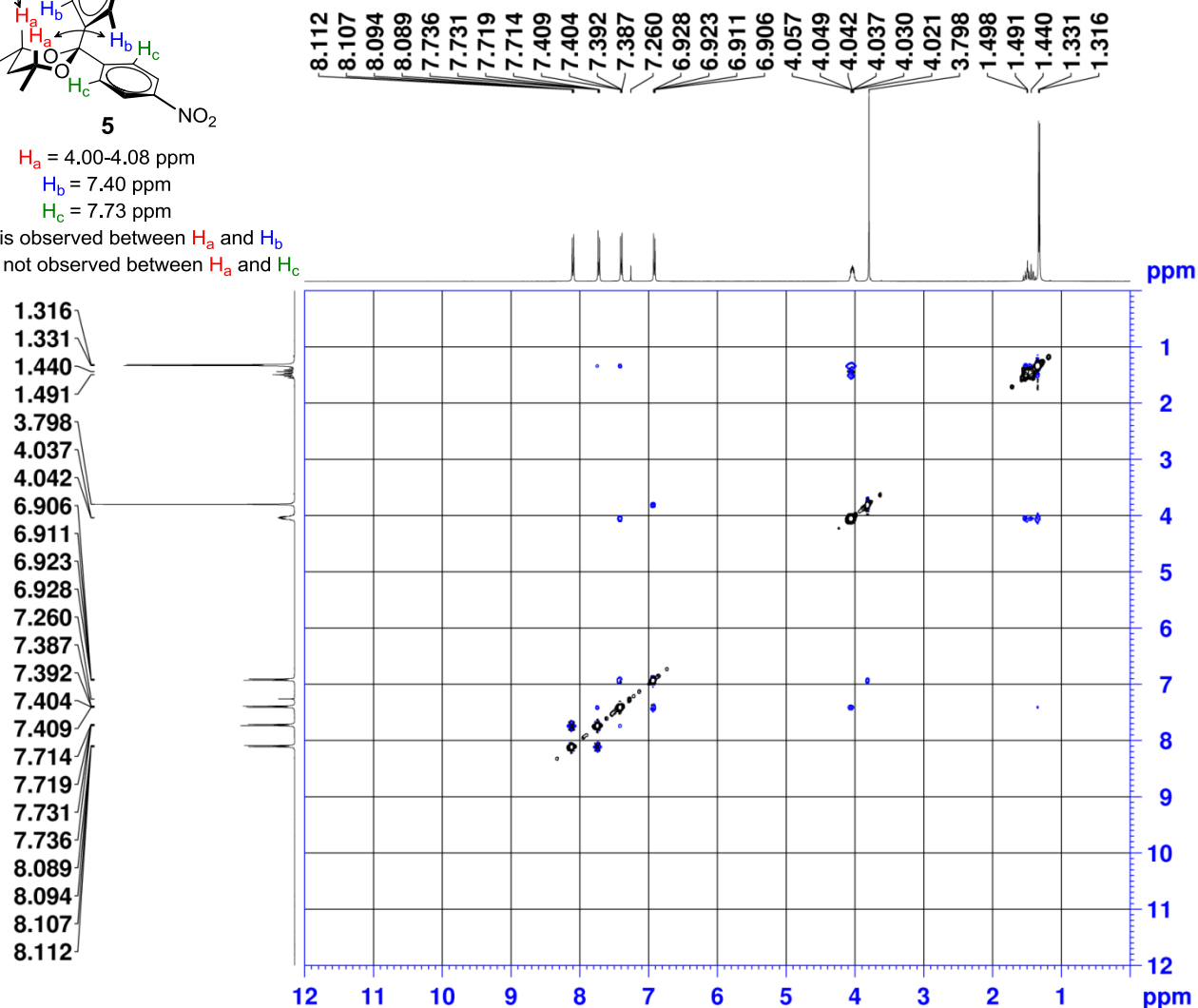
$H_a = 4.00-4.08$ ppm

$H_b = 7.40$ ppm

$H_c = 7.73$ ppm

A NOE is observed between H_a and H_b

A NOE is not observed between H_a and H_c



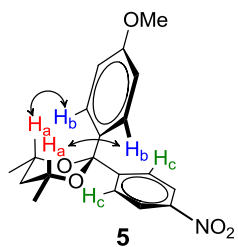
Current Data Parameters
NAME KL-1-47-isomer10-1H-NOESY-
EXPNO 1
PROCNO 2

F2 - Acquisition Parameters
Date_ 20130904
Time 22.58
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesypphpp
TD 2670
SOLVENT CDCl3
NS 8
DS 32
SWH 8012.820 Hz
FIDRES 3.001056 Hz
AQ 0.1666080 sec
RG 90.5
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
d0 -0.00001910 sec
D1 2.00000000 sec
D8 0.44999999 sec
d11 0.03000000 sec
d12 0.00020000 sec
D16 0.00020000 sec
in0 0 sec
STICNT 128
TAU 0.22379999 sec
dDorig -0.00001910 sec
philoop 0
t1loop 0
SFO1 400.1464009 MHz
NUC1 1H
P1 15.00 usec
p2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W
GPNAM[1] SMSQ10.100
GP21 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 668
SFO1 400.1464 MHz
FIDRES 11.995227 Hz
SW 20.025 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0



$H_a = 4.00\text{--}4.08\text{ ppm}$

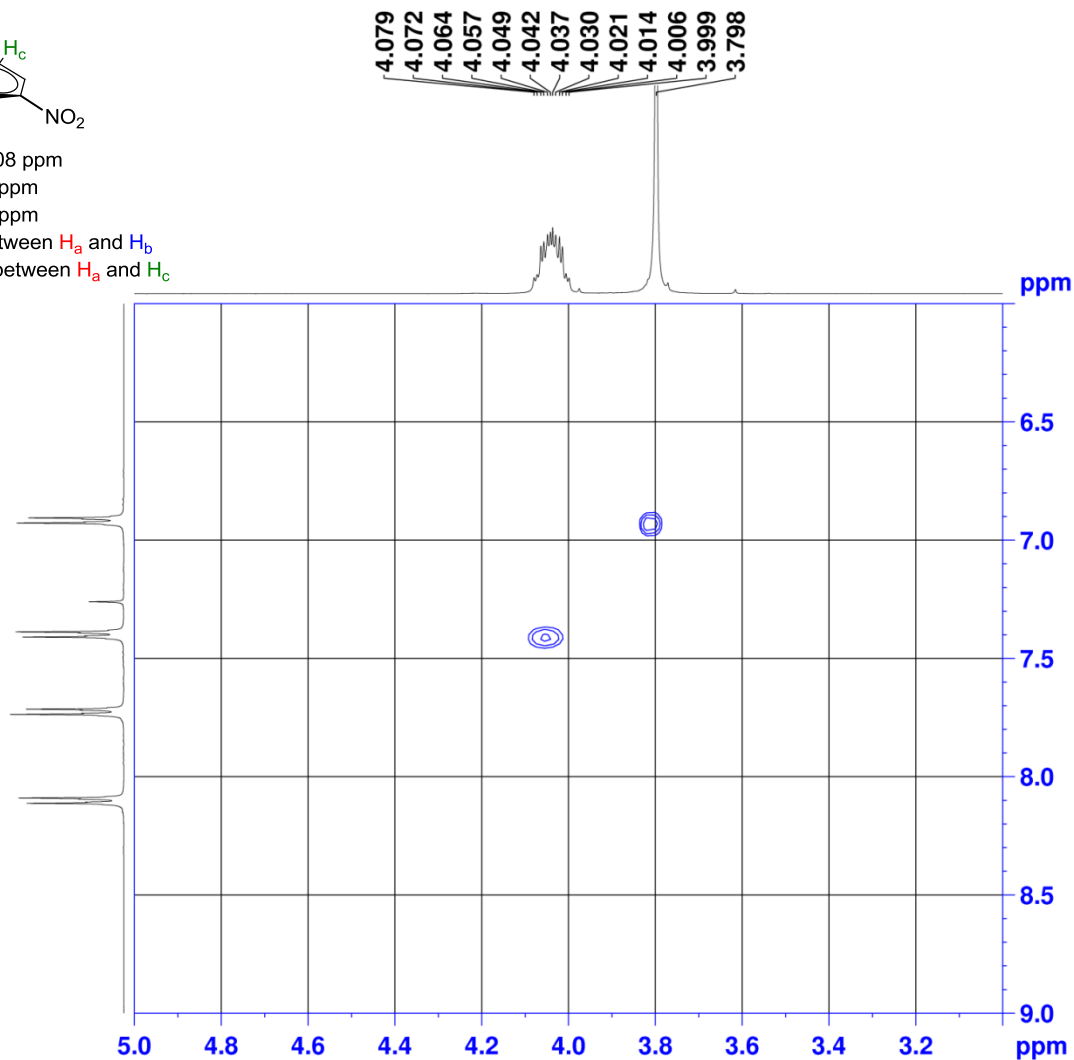
$H_b = 7.40\text{ ppm}$

$H_c = 7.73\text{ ppm}$

A NOE is observed between H_a and H_b

A NOE is not observed between H_a and H_c

6.906
6.911
6.923
6.928
7.260
7.387
7.392
7.404
7.409
7.714
7.719
7.731
7.736
8.089
8.094
8.107
8.112



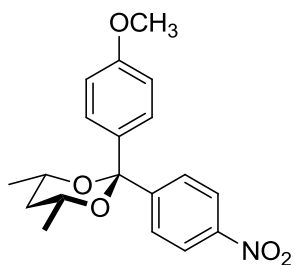
Current Data Parameters
NAME KL-1-47-isomer10-1H-NOESY-
EXPNO 1
PROCNO 2

F2 - Acquisition Parameters
Date_ 20130904
Time 22.58
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesypphpp
TD 2670
SOLVENT CDCl3
NS 8
DS 32
SWH 8012.820 Hz
FIDRES 3.001056 Hz
AQ 0.1666080 sec
RG 90.5
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
d0 -0.00001910 sec
D1 2.00000000 sec
D8 0.44999999 sec
d11 0.03000000 sec
d12 0.00020000 sec
D16 0.00020000 sec
in0 0 sec
STICNT 128
TAU 0.22379999 sec
dDorig -0.00001910 sec
philocp 0
t1loop 0
SFO1 400.1464009 MHz
NUC1 1H
P1 15.00 usec
p2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W
GPNAM[1] SMSQ10.100
GP21 40.00 %
P16 1000.00 usec

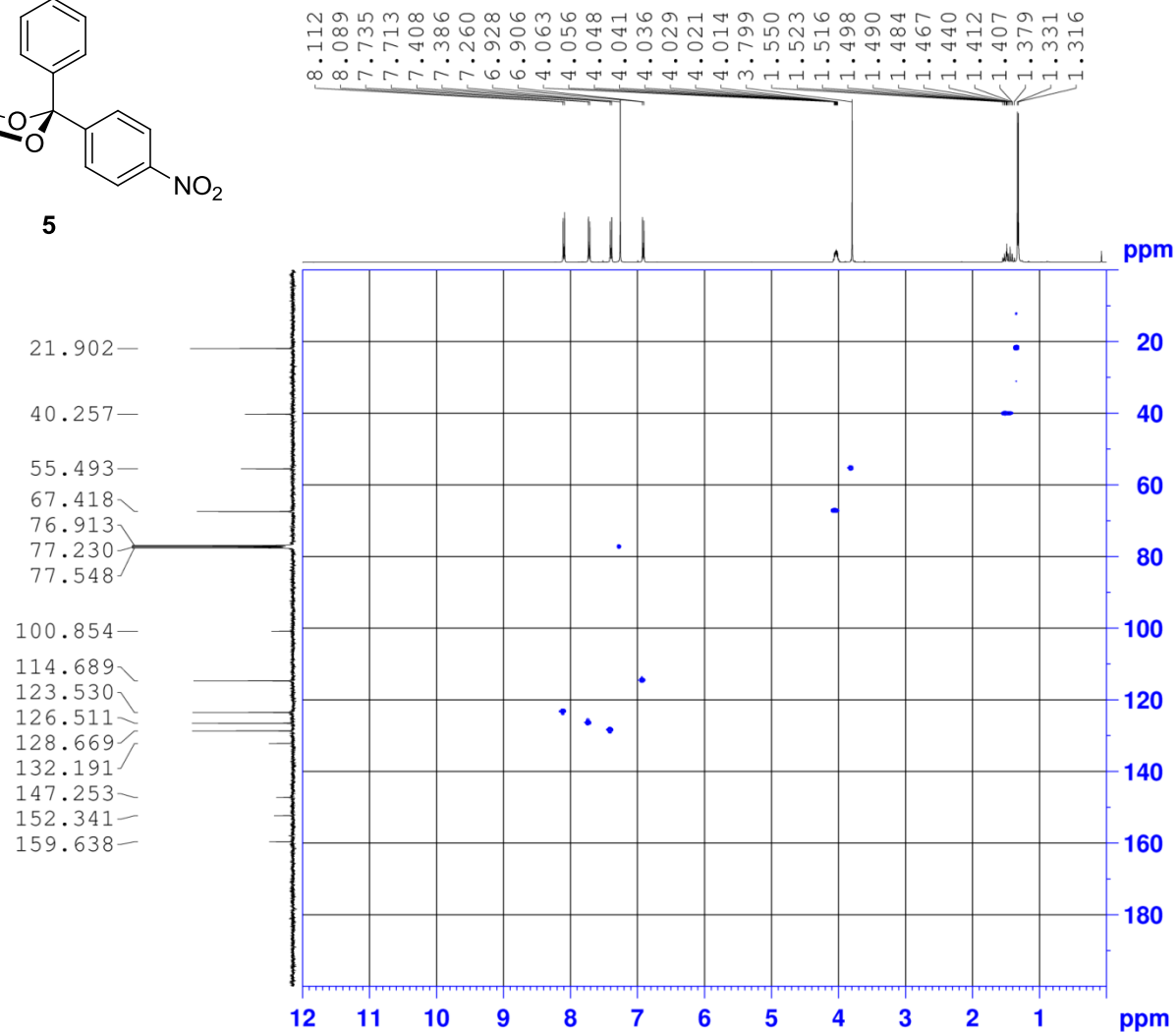
F1 - Acquisition parameters
TD 668
SFO1 400.1464 MHz
FIDRES 11.995227 Hz
SW 20.025 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0



5



Current Data Parameters
NAME kl-47-HSQC-11
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20140928
Time 21.00
INSTRUM spect
PROBHD 5 mm PASDB BB/
PULPROG hsqcetgp
TD 1024
SOLVENT CDCl3
NS 2
DS 16
SWH 5341.880 Hz
FIDRES 5.216680 Hz
AQ 0.8958464 sec
RG 203
DW 93.600 usec
DE 6.50 usec
TE 300.0 K
CNST2 145.0000000
d0 0.0000000 sec
d1 1.5000000 sec
d4 0.00172414 sec
d11 0.03000000 sec
d16 0.00020000 sec
DELTA 0.00123600 sec
DELTA1 0.00071919 sec
in0 0 sec
STICNT 128
ZGPTNS
d0orig 0.00000300 sec
philoop 0
t1loop 0
SF01 400.1464057 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P28 1000.00 usec
PLW1 12.00000000 W
SF02 100.6237933 MHz
NUC2 13C
CPDPRG2 garp
P3 10.00 usec
P4 20.00 usec
PCPD2 80.00 usec
PLW2 50.00000000 W
PLW12 0.78125000 W
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GP1 80.00 %
GP2 20.10 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SF01 100.6238 MHz
FIDRES 65.106445 Hz
SW 165.639 ppm
FnMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162890 MHz
WDW USER
SSB 2
LB 0 Hz
GB 0

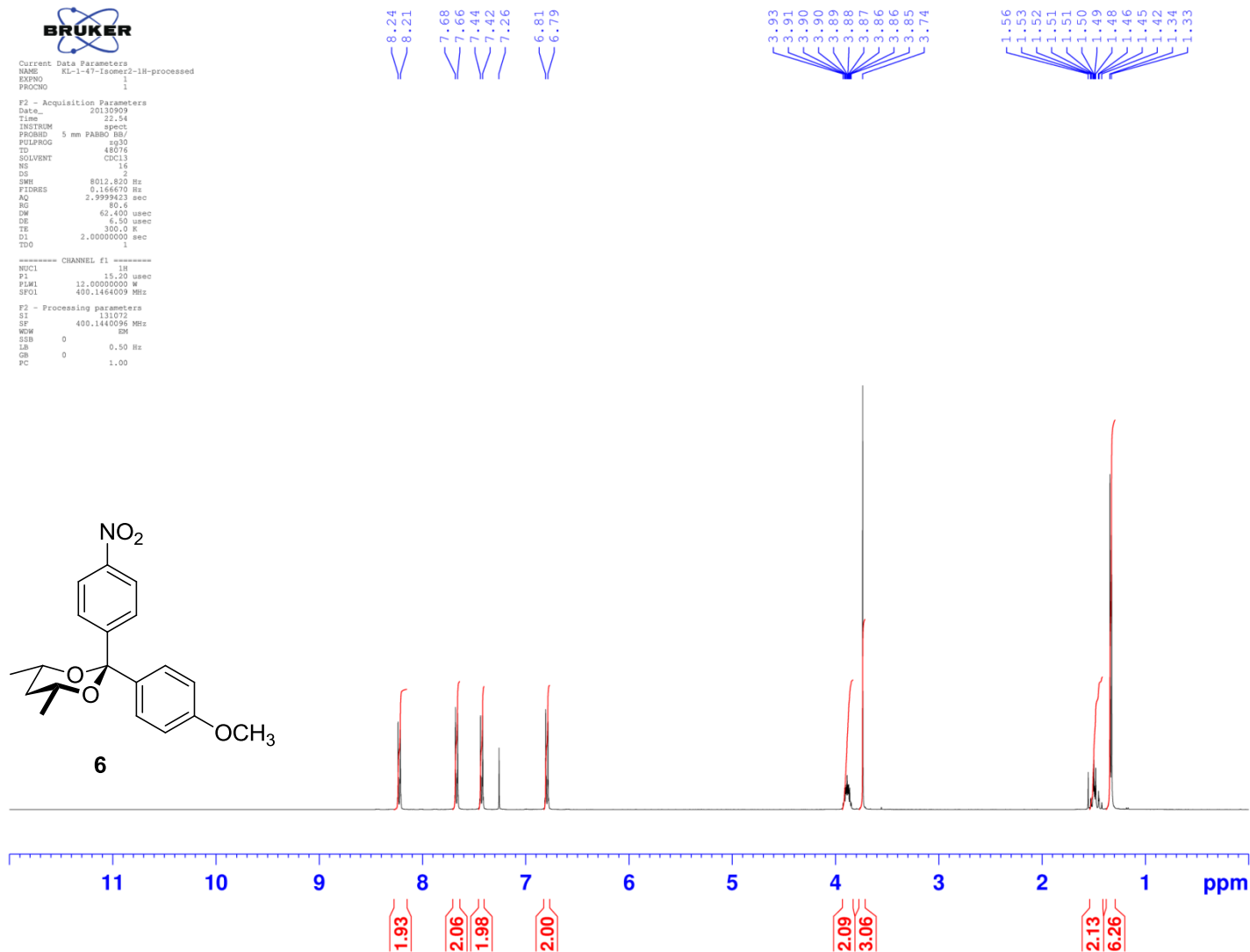
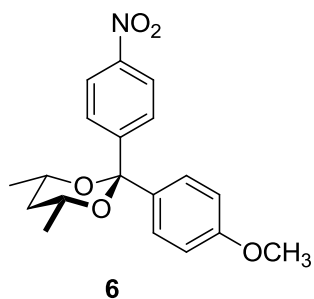



Current Data Parameters
NAME KL-1-47-Isomer2-18-processed
EXPNO 1
PROCNO 1

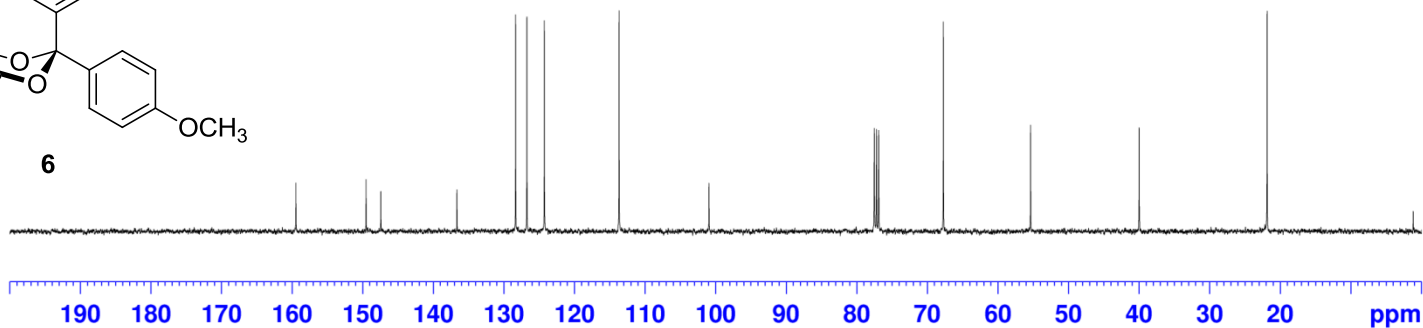
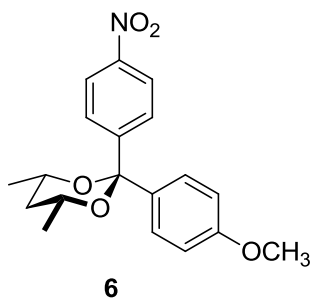
F2 - Acquisition Parameters
Date_ 20130909
Time 22.54
INSTRUM spect
PROBHD 5 mm PABBO BBO
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 80.6
OW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

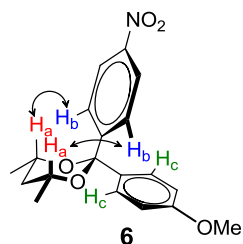
----- CHANNEL f1 -----
NUC1 1H
P1 15.20 usec
PL1 12.00000000 W
SF01 400.1464009 MHz

F2 - Processing parameters
SI 131072
SF 400.1440096 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00




 Current Data Parameters
 NAME K2-1-47-isomer2-C-processed
 EXPNO 2
 PROCNO 1
 F2 - Acquisition Parameters
 Date_ 20130823
 Time 1:48
 INSTRUM spect
 PROBRD 5 mm PABBO BB/
 PULPROG zgpg30
 TD 65536
 SOLVENT CDCl3
 NS 62
 DS 4
 SWH 24038.461 Hz
 FIDRES 0.550104 Hz
 AQ 0.9089184 sec
 RG 203
 DW 20.800 usec
 DE 6.50 usec
 TE 300.0 K
 D1 1.50000000 sec
 d11 0.03000000 sec
 DELTA 1.39999998 sec
 TD0 1
 SFO1 100.6263500 MHz
 NUC1 13C
 P1 10.00 usec
 PL1 50.00299825 W
 SFO2 400.1456006 MHz
 NUC2 1H
 CTDPRG2 wait16
 PCPD2 90.00 usec
 PL2 12.00000000 W
 PL12 0.33333001 W
 PL13 0.27000001 W
 F2 - Processing parameters
 SI 131072
 SF 100.6162760 MHz
 WDW EM
 SSB 0
 LB 2.50 Hz
 GB 0
 PC 1.40



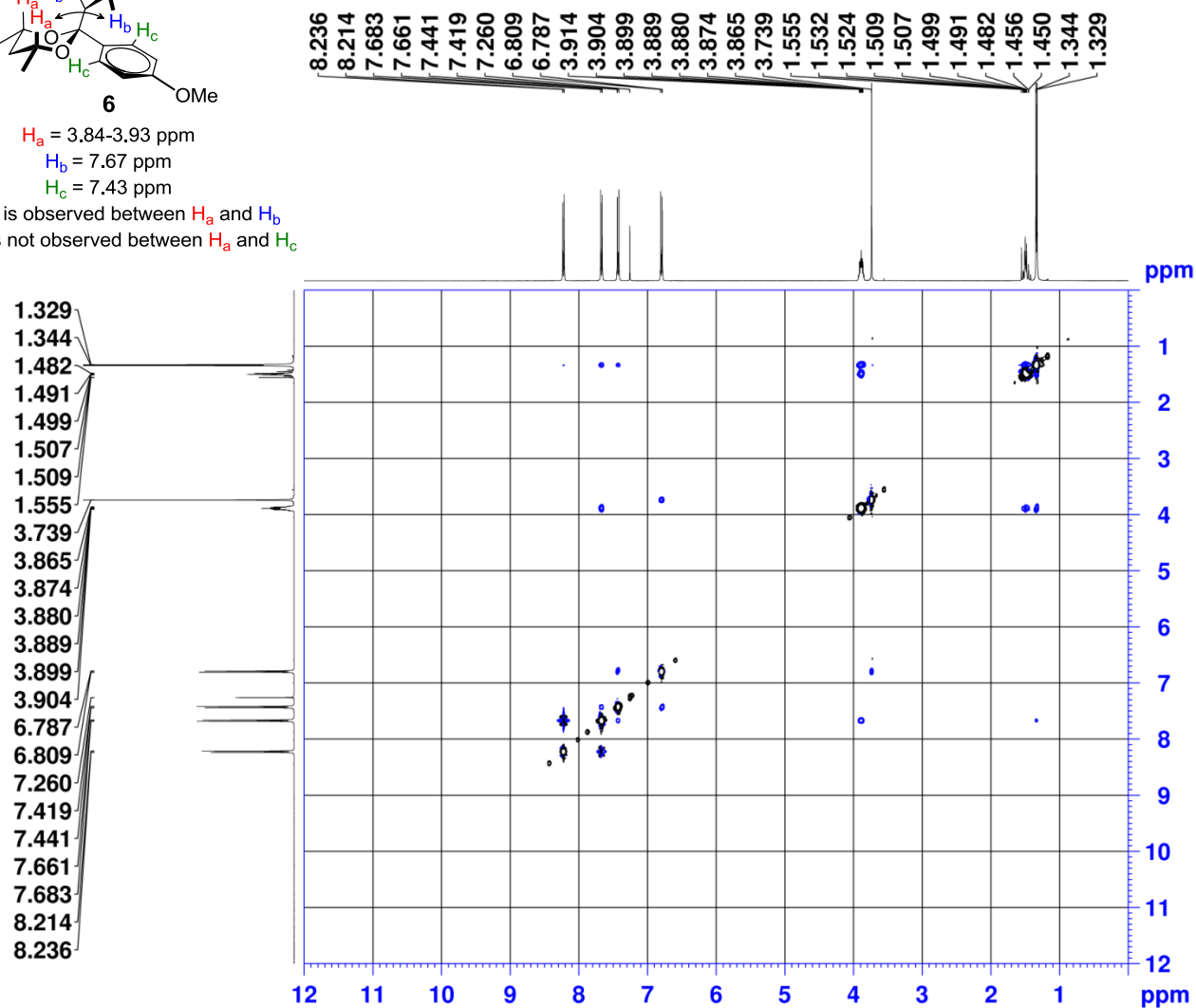


$H_a = 3.84\text{--}3.93\text{ ppm}$

$H_b = 7.67\text{ ppm}$

$H_c = 7.43\text{ ppm}$

A NOE is observed between H_a and H_b
 A NOE is not observed between H_a and H_c



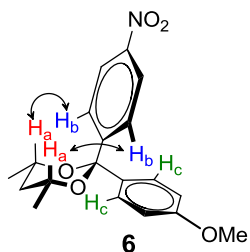
Current Data Parameters
 NAME KL-1-47-Isomer2-1H-NOESY
 EXPNO 1
 PROCNO 2

F2 - Acquisition Parameters
 Date_ 20130909
 Time 23.08
 INSTRUM spect
 PROBHD 5 mm PABBO BB/
 PULPROG noesypphph
 TD 2670
 SOLVENT CDCl3
 NS 8
 DS 32
 SWH 8012.820 Hz
 FIDRES 3.001056 Hz
 AQ 0.1666080 sec
 RG 80.6
 DW 62.400 usec
 DE 6.50 usec
 TE 300.0 K
 d0 -0.00001910 sec
 D1 2.00000000 sec
 D8 0.44999999 sec
 d11 0.03000000 sec
 d12 0.00002000 sec
 D16 0.00020000 sec
 In0 0 sec
 STICNT 128
 TAU 0.22379999 sec
 d0orig -0.00001910 sec
 phloop 0
 t1loop 0
 SFO1 400.1464009 MHz
 NUC1 1H
 P1 15.00 usec
 p2 30.00 usec
 P17 2500.00 usec
 PLW1 12.00000000 W
 PLW10 3.99410009 W
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 616
 SFO1 400.1464 MHz
 FIDRES 13.007792 Hz
 SW 20.025 ppm
 FhMODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440083 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440083 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0



$H_a = 3.84\text{--}3.93\text{ ppm}$

$H_b = 7.67\text{ ppm}$

$H_c = 7.43\text{ ppm}$

A NOE is observed between H_a and H_b

A NOE is not observed between H_a and H_c

3.930
3.914
3.904
3.899
3.889
3.880
3.874
3.865
3.859
3.849
3.739



Current Data Parameters
NAME KL-1-47-Isomer2-1H-NOESY
EXPNO 1
PROCNO 2

F2 - Acquisition Parameters
Date_ 20130909
Time 23.08
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesypphph
TD 2670
SOLVENT CDCl3
NS 8
DS 32
SWH 8012.820 Hz
FIDRES 3.001056 Hz
AQ 0.1666080 sec
RG 80.6
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
d0 -0.00001910 sec
D1 2.00000000 sec
D8 0.44999999 sec
d11 0.03000000 sec
d12 0.00002000 sec
D16 0.00020000 sec
In0 0 sec
STICNT 128
TAU 0.22379999 sec
d0orig -0.00001910 sec
philoop 0
tllloop 0
SFO1 400.1464009 MHz
NUC1 1H
P1 15.00 usec
p2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W
GPNAM[1] SMSQ10.100
GP21 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 616
SFO1 400.1464 MHz
FIDRES 13.007792 Hz
SW 20.025 ppm
FhMODE States-TPPI

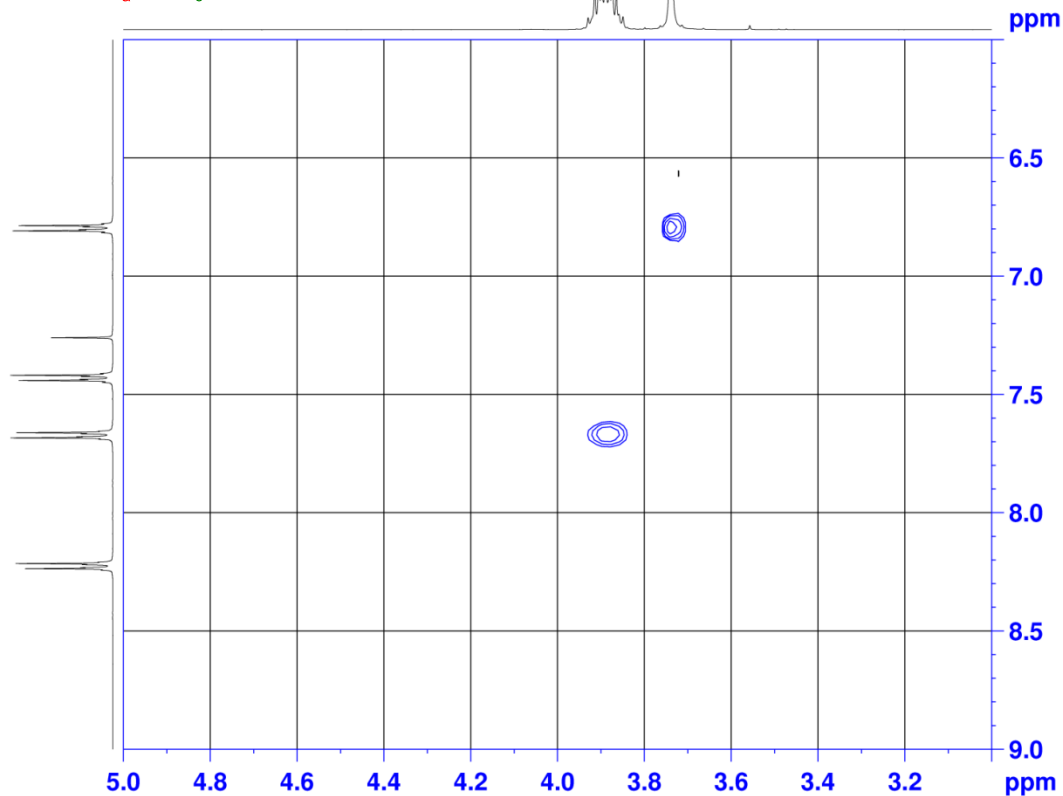
F2 - Processing parameters
SI 1024
SF 400.1440083 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

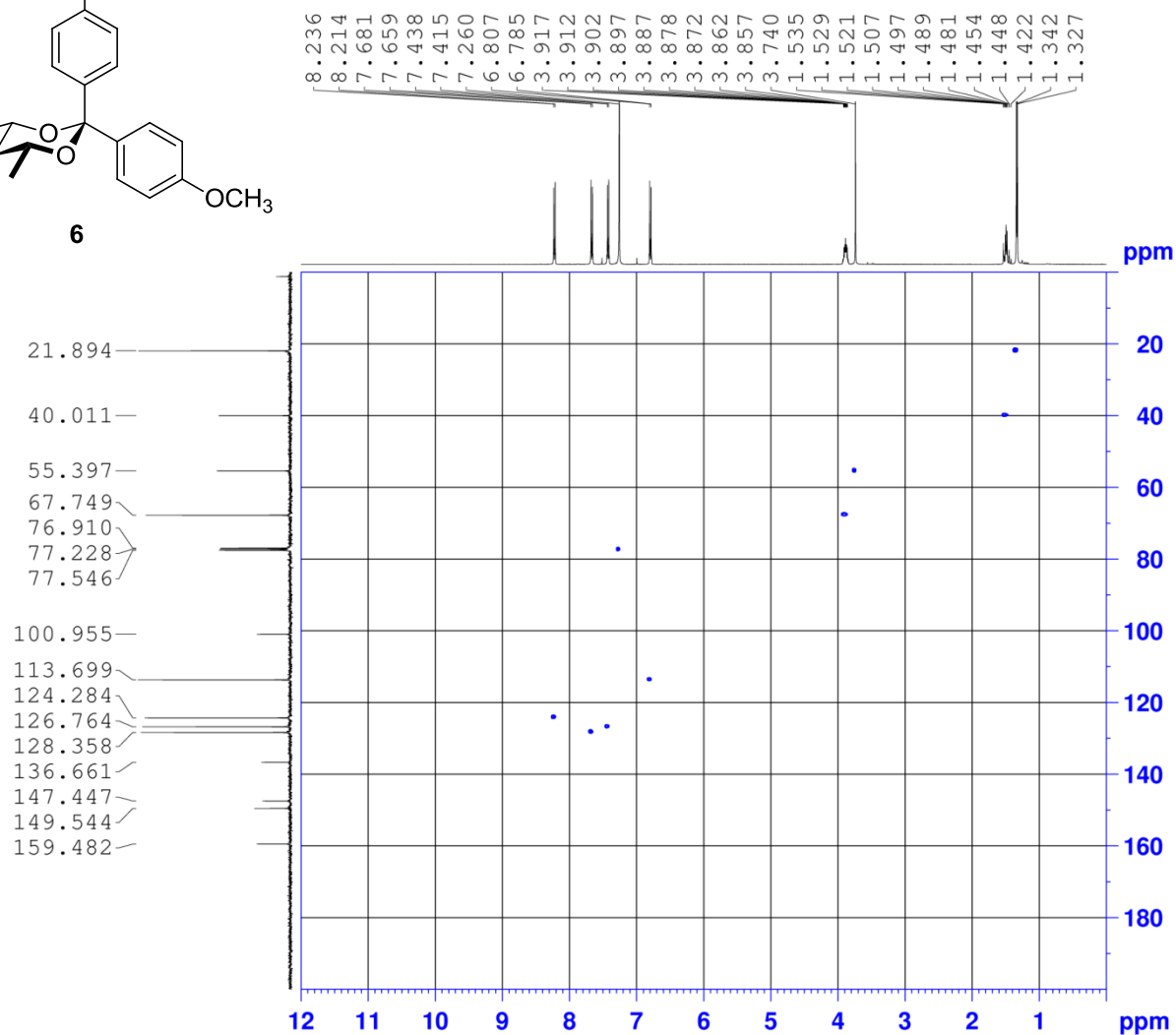
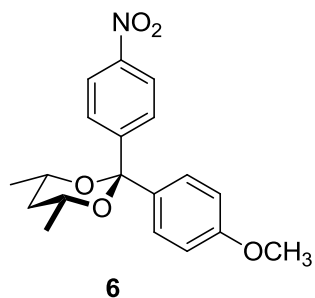
F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440083 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0

6.787
6.809

7.260
7.419
7.441
7.661
7.683

8.214
8.236





Current Data Parameters
NAME kl-47-HSQC-12
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20140928
Time 21.25
INSTRUM spect
PROBHD 5 mm PASBO BB/
PULPROG hsqcetgp
TD 1024
SOLVENT CDCl3
NS 2
DS 16
SWH 5341.880 Hz
FIDRES 5.216680 Hz
AQ 0.8958464 sec
RG 203
DW 93.600 usec
DE 6.50 usec
TE 300.0 K
CNST2 145.0000000
d0 0.0000000 sec
d1 1.5000000 sec
d4 0.00172414 sec
d11 0.03000000 sec
d16 0.00020000 sec
DELTA 0.00123600 sec
DELTA1 0.00071919 sec
in0 0 sec
STCNT 128
ZGPTNS
d0orig 0.00000300 sec
philoop 0
t1loop 0
SF01 400.1464057 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P28 1000.00 usec
PLW1 12.0000000 W
SF02 100.6237933 MHz
NUC2 13C
CPDPRG2 garp
P3 10.00 usec
P4 20.00 usec
PCPD2 80.00 usec
PLW2 50.0000000 W
PLW12 0.78125000 W
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GP1 80.00 %
GP2 20.10 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SF01 100.6238 MHz
FIDRES 65.106445 Hz
SW 165.639 ppm
FnMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162890 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0

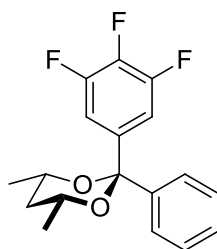


Current Data Parameters
NAME KL-93-Lower spot-processed isomer 1
EXPNO 1
PROCNO 1

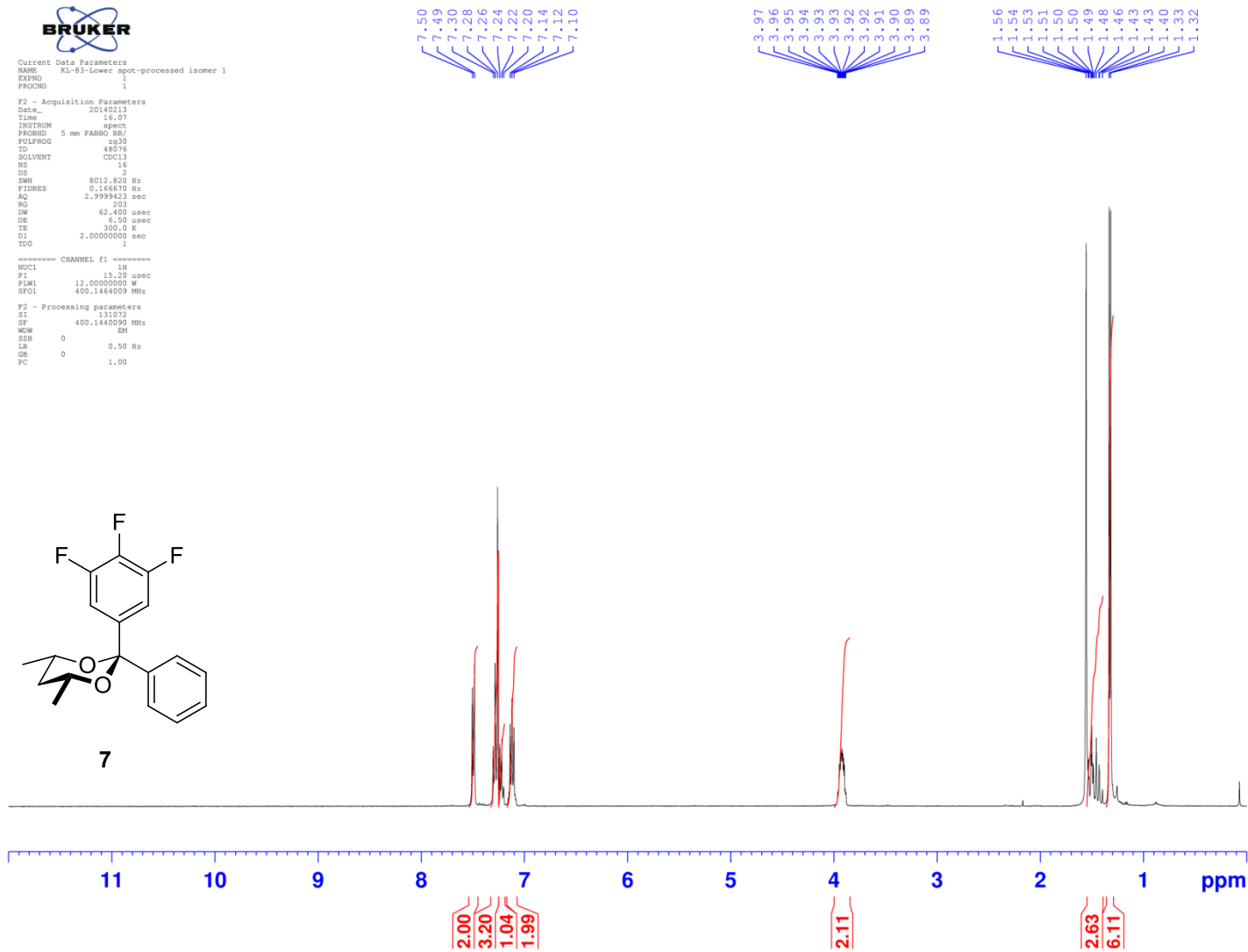
F2 - Acquisition Parameters
Date_ 20140213
Time 16.07
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999421 sec
RG 203
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TDO 1

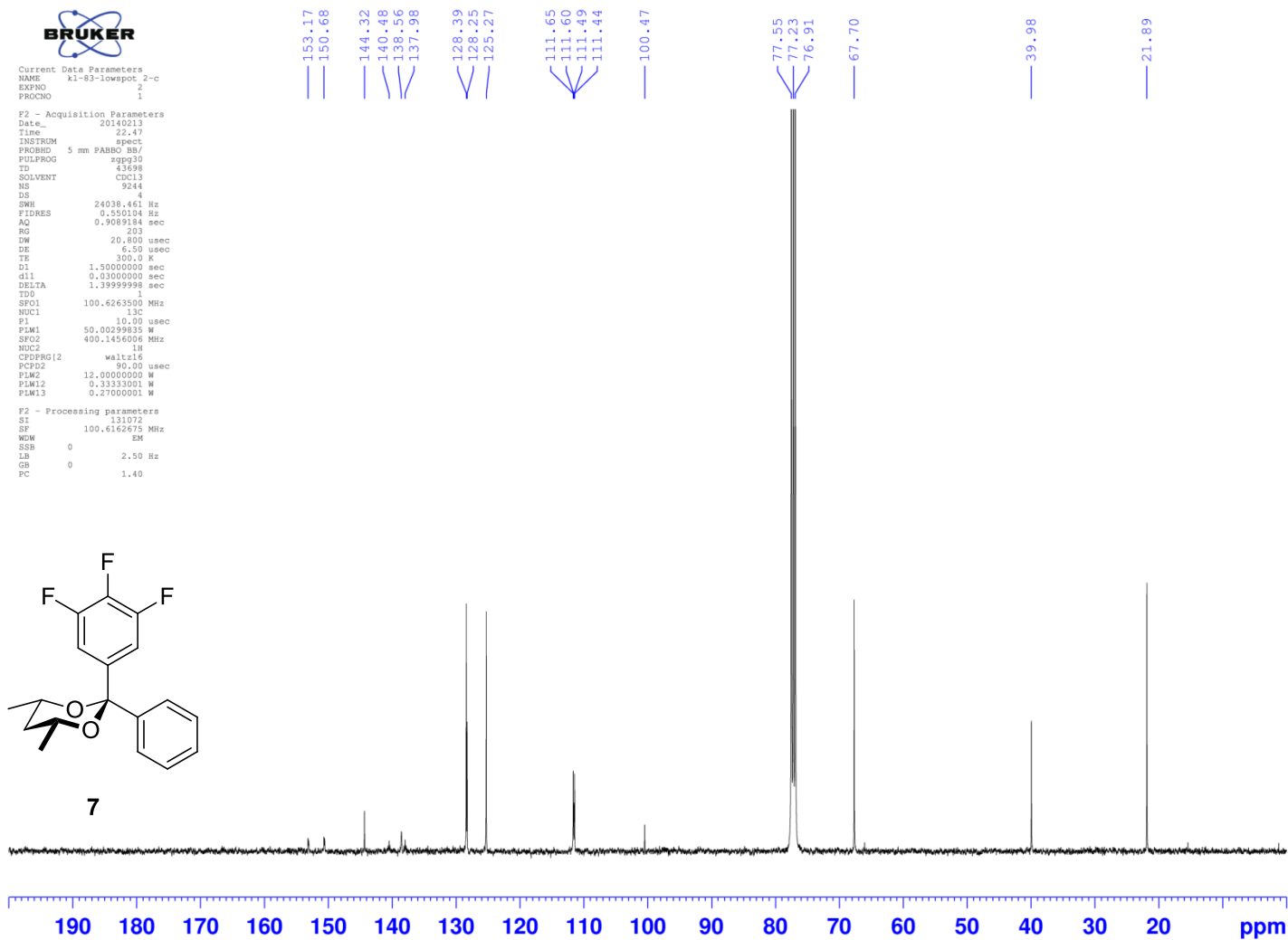
===== CHANNEL f1 =====
NUC1 1H
P1 15.20 usec
P1M1 12.0000000 W
SFO1 400.1464009 MHz

F2 - Processing parameters
SI 131072
SF 400.1464009 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00



7







Current Data Parameters
NAME KL-83-Lower Spot F-19-processed
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20140214
Time 20.15
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 131072
SOLVENT CDCl3
NS 16
DS 4
SWH 89285.711 Hz
FIDRES 0.681196 Hz
AQ 0.7340032 sec
RG 203
DM 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 1.00000000 sec
TDO 1

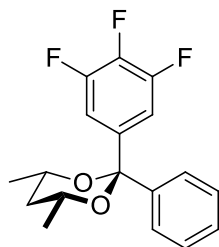
===== CHANNEL f1 =====
NUC1 19F
P1 14.00 usec
PLW1 18.00000000 W
SFO1 376.4738882 MHz

F2 - Processing parameters
SI 65536
SF 376.5116933 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

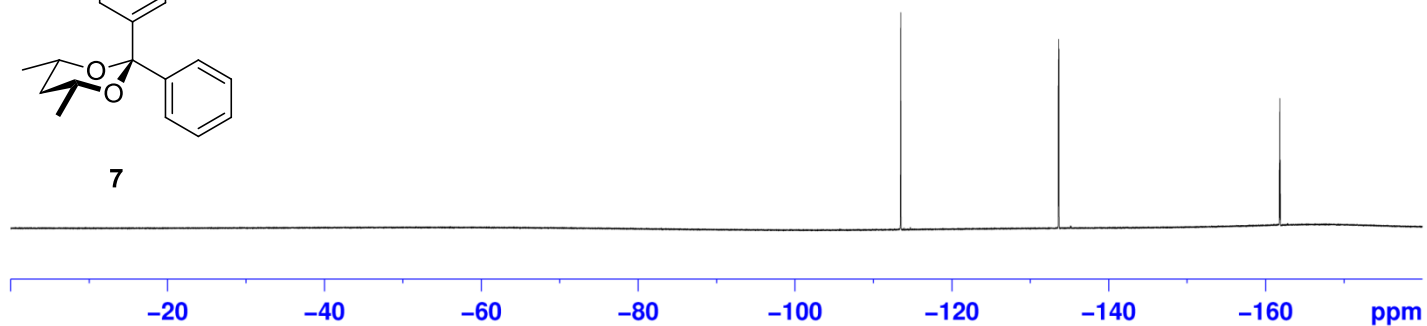
113.48
113.48
113.50
113.52
113.52

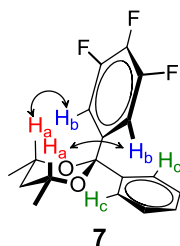
133.59
133.62
133.65
133.67

161.76
161.79
161.81
161.83
161.87



7



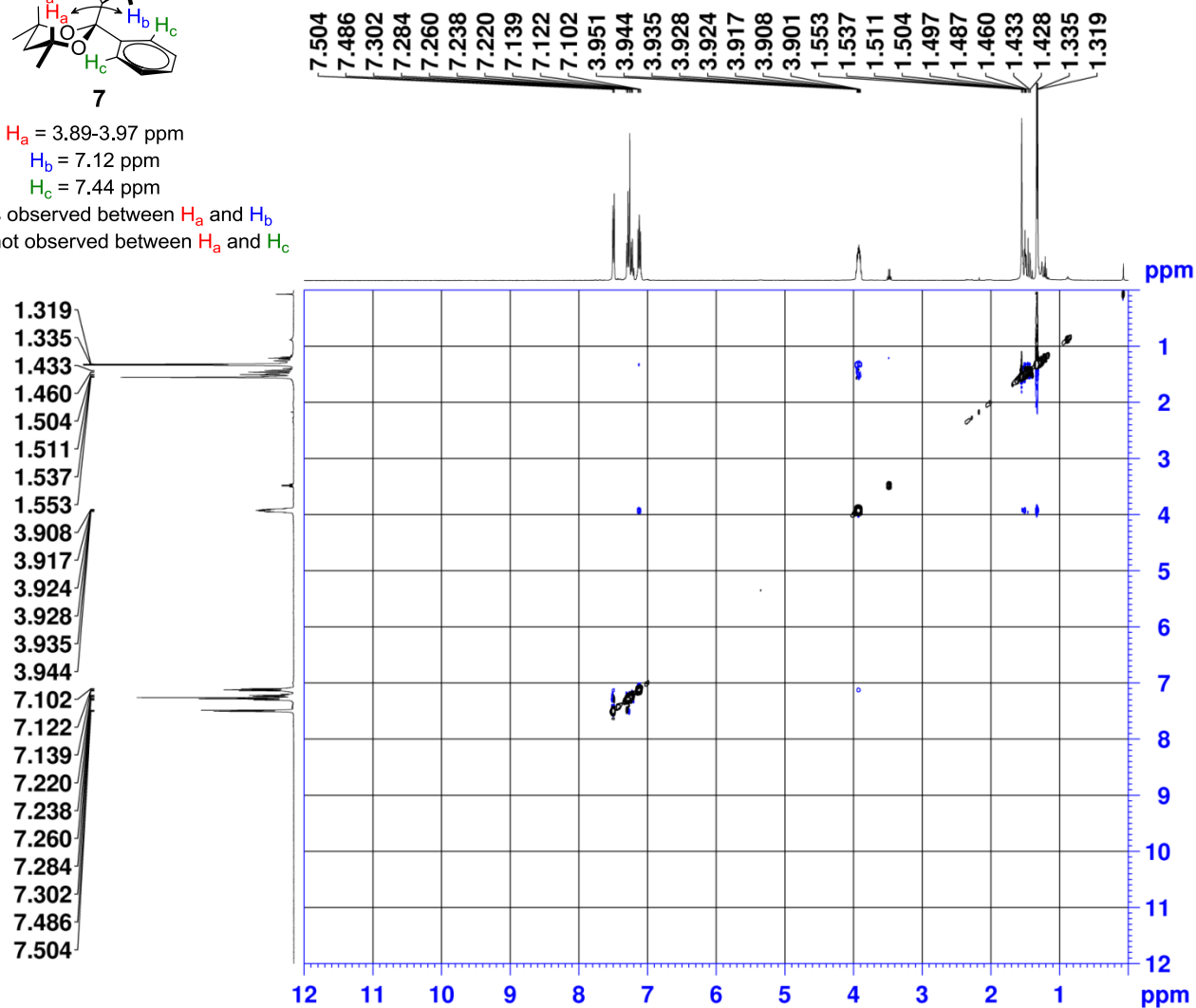


$H_a = 3.89\text{--}3.97\text{ ppm}$

$H_b = 7.12\text{ ppm}$

$H_c = 7.44\text{ ppm}$

A NOE is observed between H_a and H_b
 A NOE is not observed between H_a and H_c



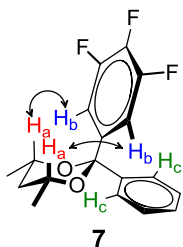
Current Data Parameters
 NAME kl-83-lowspot 2-HNOESY-processed
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20140213
 Time 23:15
 INSTRUM spect
 PROBHD 5 mm PABBO BB/
 PULPROG noesypphpgp
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 32
 SWH 4084.967 Hz
 FIDRES 1.994613 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 d0 -0.00001910 sec
 D1 2.00000000 sec
 D8 0.63999999 sec
 d11 0.03000000 sec
 d12 0.00002000 sec
 D16 0.00020000 sec
 in0 0 sec
 STICNT 128
 TAU 0.34880000 sec
 dDorig -0.00001910 sec
 phLoop 0
 t1loop 0
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.00 usec
 P2 30.00 usec
 P17 2500.00 usec
 PLW1 12.00000000 W
 PLW10 3.99410000 W
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FhMODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440080 MHz
 WDW QSIINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440084 MHz
 WDW QSIINE
 SSB 2
 LB 0 Hz
 GB 0



$H_a = 3.89\text{--}3.97\text{ ppm}$

$H_b = 7.12\text{ ppm}$

$H_c = 7.44\text{ ppm}$

A NOE is observed between H_a and H_b

A NOE is not observed between H_a and H_c

3.966
3.959
3.951
3.944
3.935
3.928
3.924
3.917
3.908
3.901
3.893
3.886



Current Data Parameters
NAME kl-83-lowspot_2-HNOSY-processed
EXPNO 1
PROCNO 1

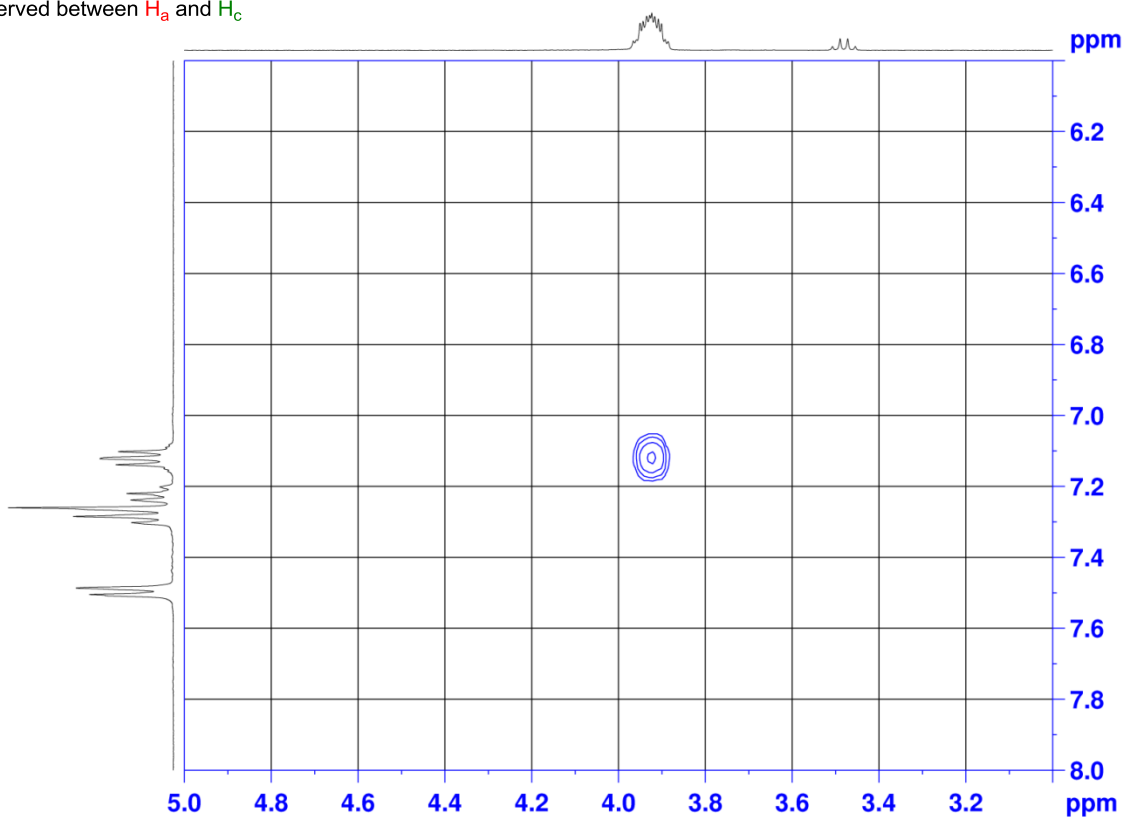
F2 - Acquisition Parameters
Date_ 20140213
Time 23:15
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG nosyppgpgp
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
d0 -0.00001910 sec
D1 2.00000000 sec
D8 0.63999999 sec
d11 0.03000000 sec
d12 0.00002000 sec
D16 0.00020000 sec
in0 0 sec
STICNT 128
TAU 0.34880000 sec
d0orig -0.00001910 sec
philoop 0
tiloop 0
SF01 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

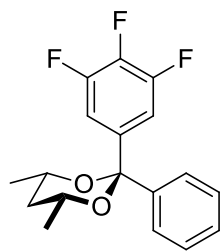
F1 - Acquisition parameters
TD 256
SF01 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FhMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440080 MHz
WDW QSIINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

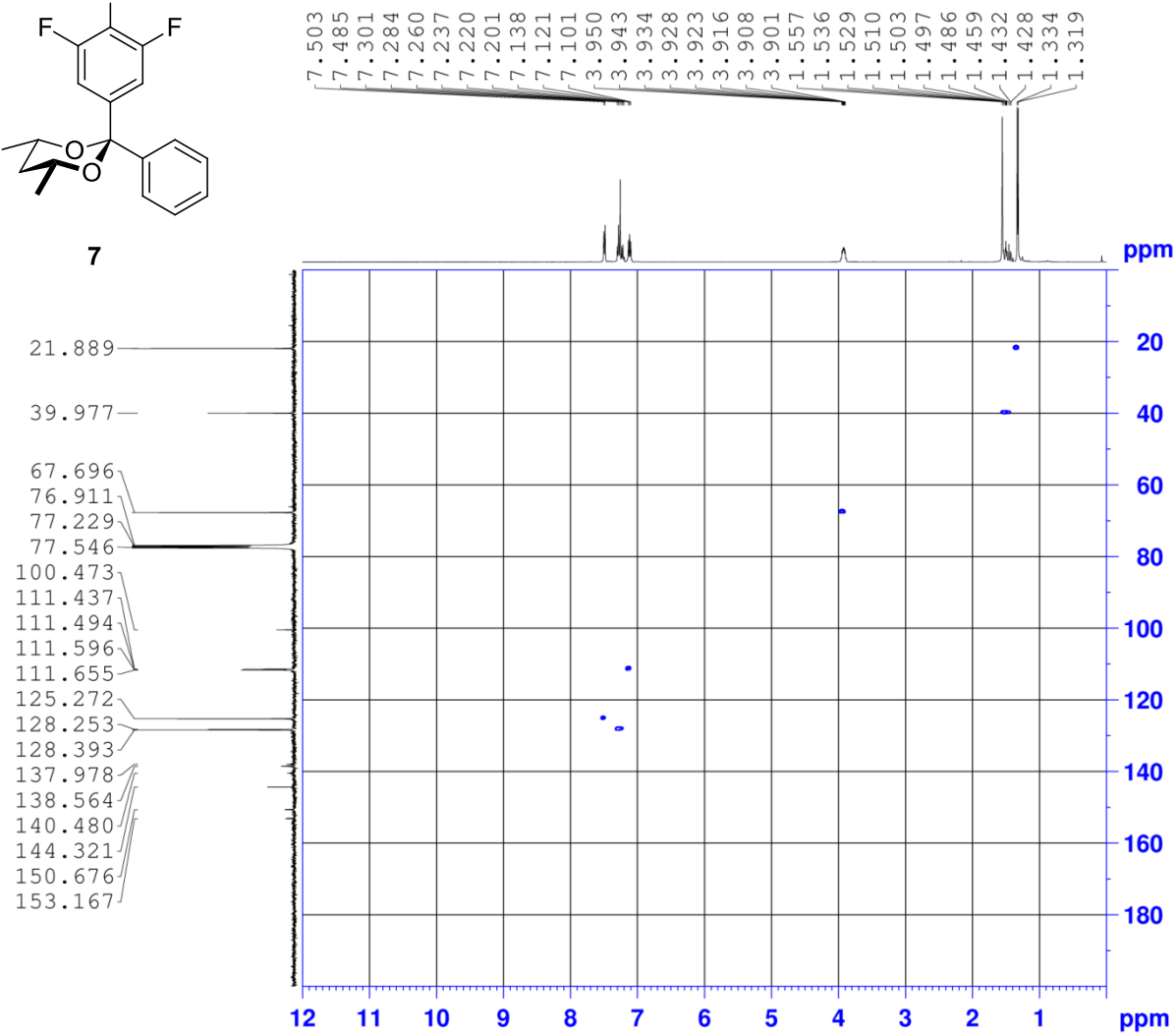
F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440084 MHz
WDW QSIINE
SSB 2
LB 0 Hz
GB 0

7.102
7.122
7.139
7.150
7.202
7.220
7.238
7.260
7.284
7.302
7.486
7.504





7



Current Data Parameters
NAME kl-83-lowspot 2-HSQC
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20140213
Time 22.56
INSTRUM spect
PROBHD 5 mm PASDD BB/
PULPROG hsqcetgp
TD 1024
SOLVENT CDC13
NS 2
DS 16
SWH 5341.880 Hz
FIDRES 5.216680 Hz
AQ 0.8958464 sec
RG 203
DW 93.600 usec
DE 6.50 usec
TE 300.0 K
CNST2 145.0000000
d0 0.0000000 sec
d1 1.5000000 sec
d4 0.00172414 sec
d11 0.03000000 sec
d16 0.00020000 sec
DELTA 0.00123600 sec
DELTA1 0.00071919 sec
in0 0 sec
STICNT 128
ZGPTNS
d0orig 0.00000300 sec
philoop 0
t1loop 0
SF01 400.1464057 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P28 1000.00 usec
PLW1 12.00000000 W
SF02 100.6237933 MHz
NUC2 13C
CPDPRG2 garp
P3 10.00 usec
P4 20.00 usec
PCPD2 80.00 usec
PLW2 50.00000000 W
PLW12 0.78125000 W
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GP1 80.00 %
GP2 20.10 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SF01 100.6238 MHz
FIDRES 65.106445 Hz
SW 165.639 ppm
FnMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162890 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0

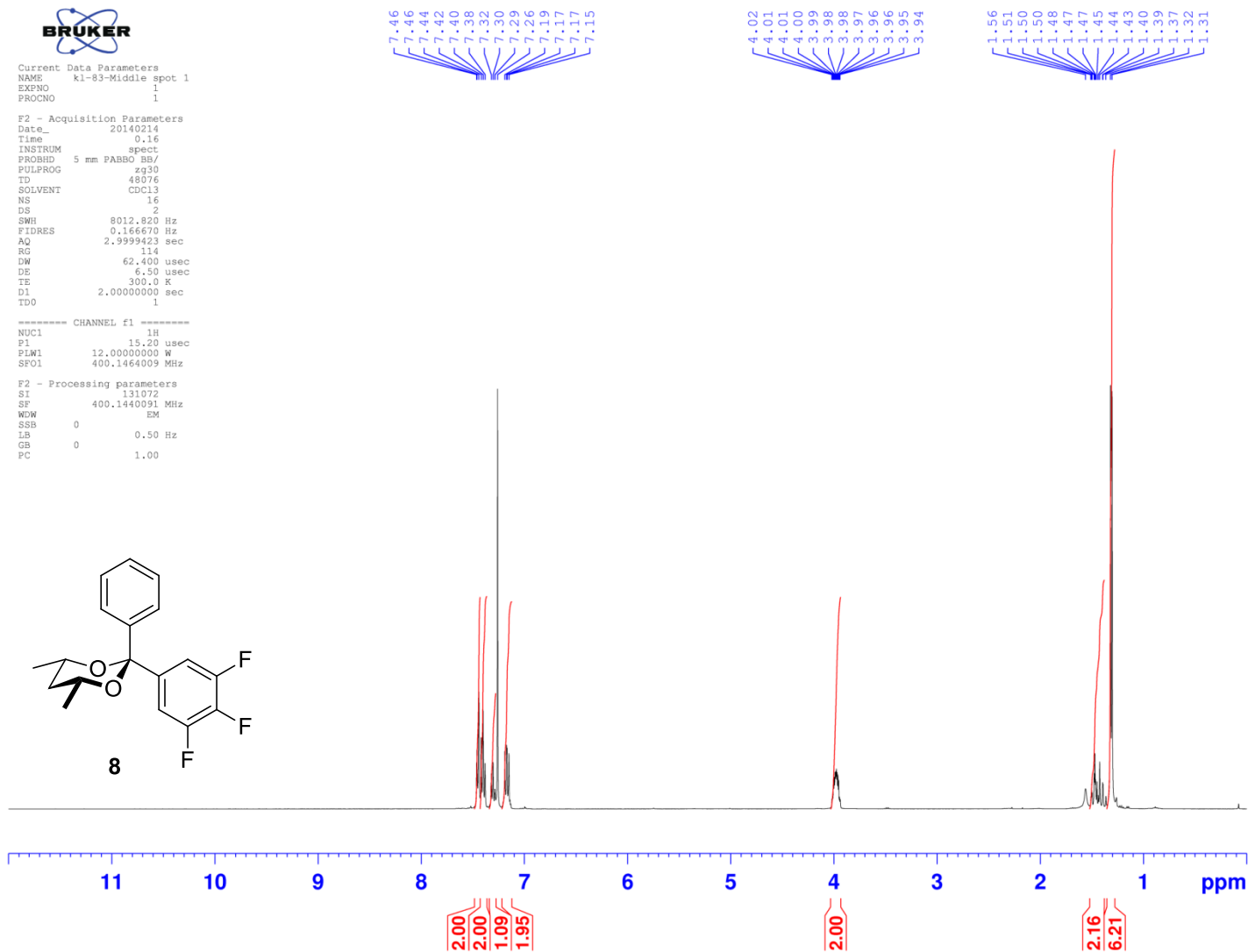
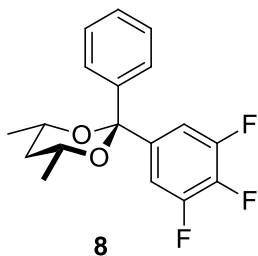


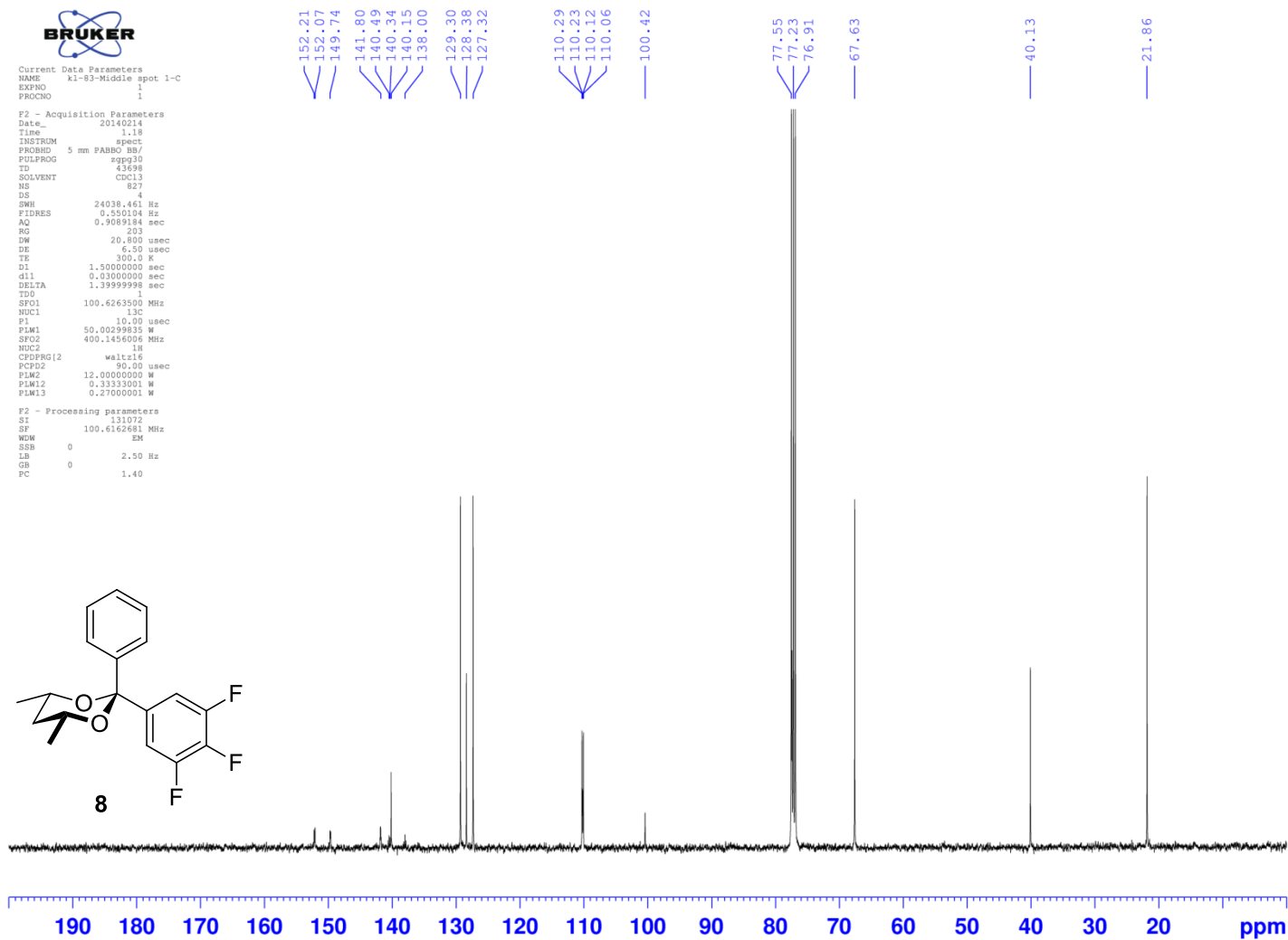
Current Data Parameters
NAME kl-83-Middle spot 1
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20140214
Time 0.16
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 114
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
NUC1 1H
P1 15.20 usec
PLW1 12.00000000 W
SFO1 400.1464009 MHz

F2 - Processing parameters
SI 131072
SF 400.1440091 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00







Current Data Parameters
NAME kl-83-Middlespot-F-19-processed
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20140214
Time 12.14
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 131072
SOLVENT CDCl3
NS 16
DS 4
SWH 89285.711 Hz
FIDRES 0.681196 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 1.00000000 sec
TD0 1

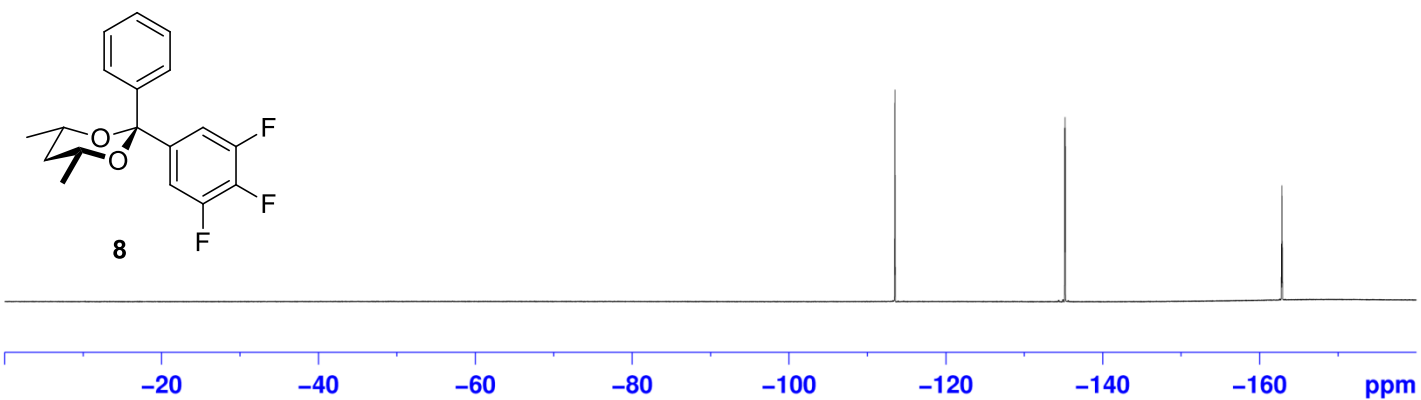
===== CHANNEL f1 =====
NUC1 19F
P1 14.00 usec
PLW1 18.00000000 W
SFO1 376.4738882 MHz

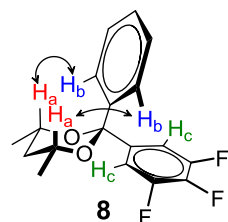
F2 - Processing parameters
SI 65536
SF 376.5116978 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

-113.47
-113.48
-113.49
-113.51
-113.52
-113.53

-135.15
-135.17
-135.18
-135.19
-135.20
-135.22
-135.23

-162.76
-162.78
-162.80
-162.82
-162.83
-162.85
-162.87
-162.89
-162.90
-162.92





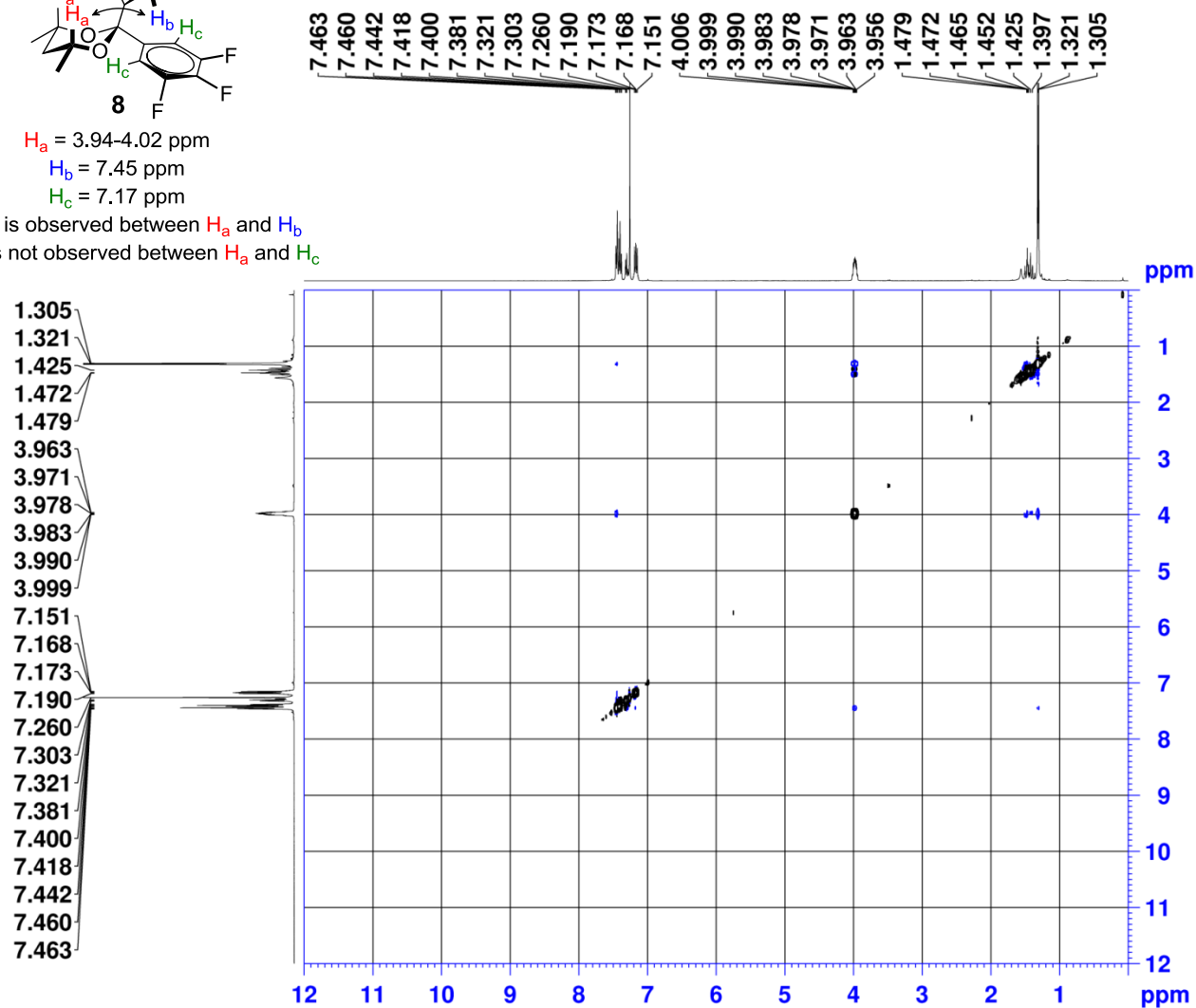
$H_a = 3.94\text{--}4.02\text{ ppm}$

$H_b = 7.45\text{ ppm}$

$H_c = 7.17\text{ ppm}$

A NOE is observed between H_a and H_b

A NOE is not observed between H_a and H_c



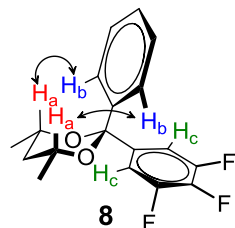
Current Data Parameters
NAME kl-83-Middle spot 1-HNOESY-
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20140214
Time 1.24
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpph
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
d0 -0.00001910 sec
D1 2.00000000 sec
D8 0.69999999 sec
d11 0.03000000 sec
d12 0.00002000 sec
D16 0.00020000 sec
in0 0 sec
STICNT 128
TAU 0.34880000 sec
d0orig -0.00001910 sec
philoop 0
t1loop 0
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W
GPNAM[1] SMSQ10.100
GP21 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440080 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440080 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0



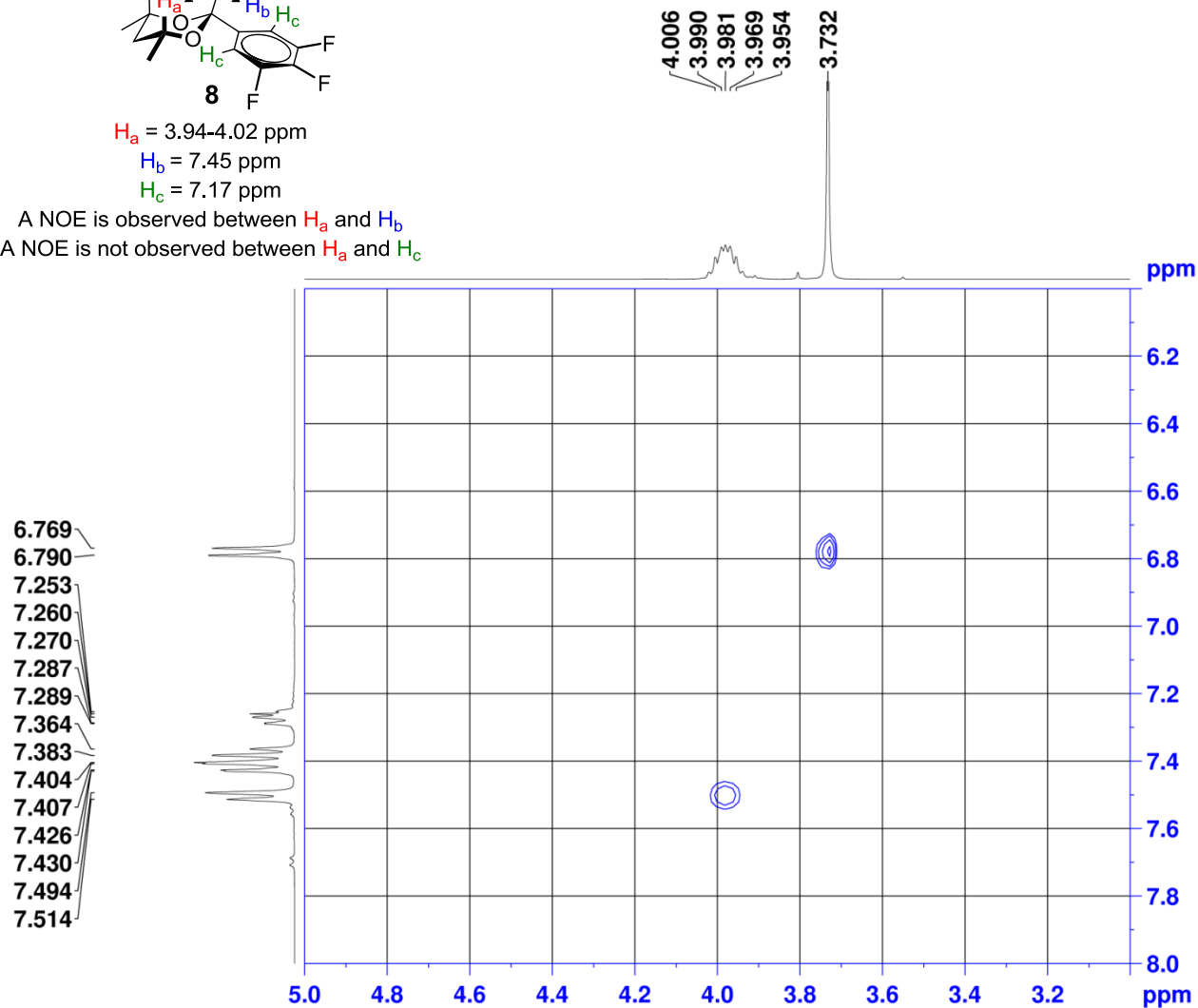
$H_a = 3.94\text{--}4.02\text{ ppm}$

$H_b = 7.45\text{ ppm}$

$H_c = 7.17\text{ ppm}$

A NOE is observed between H_a and H_b

A NOE is not observed between H_a and H_c



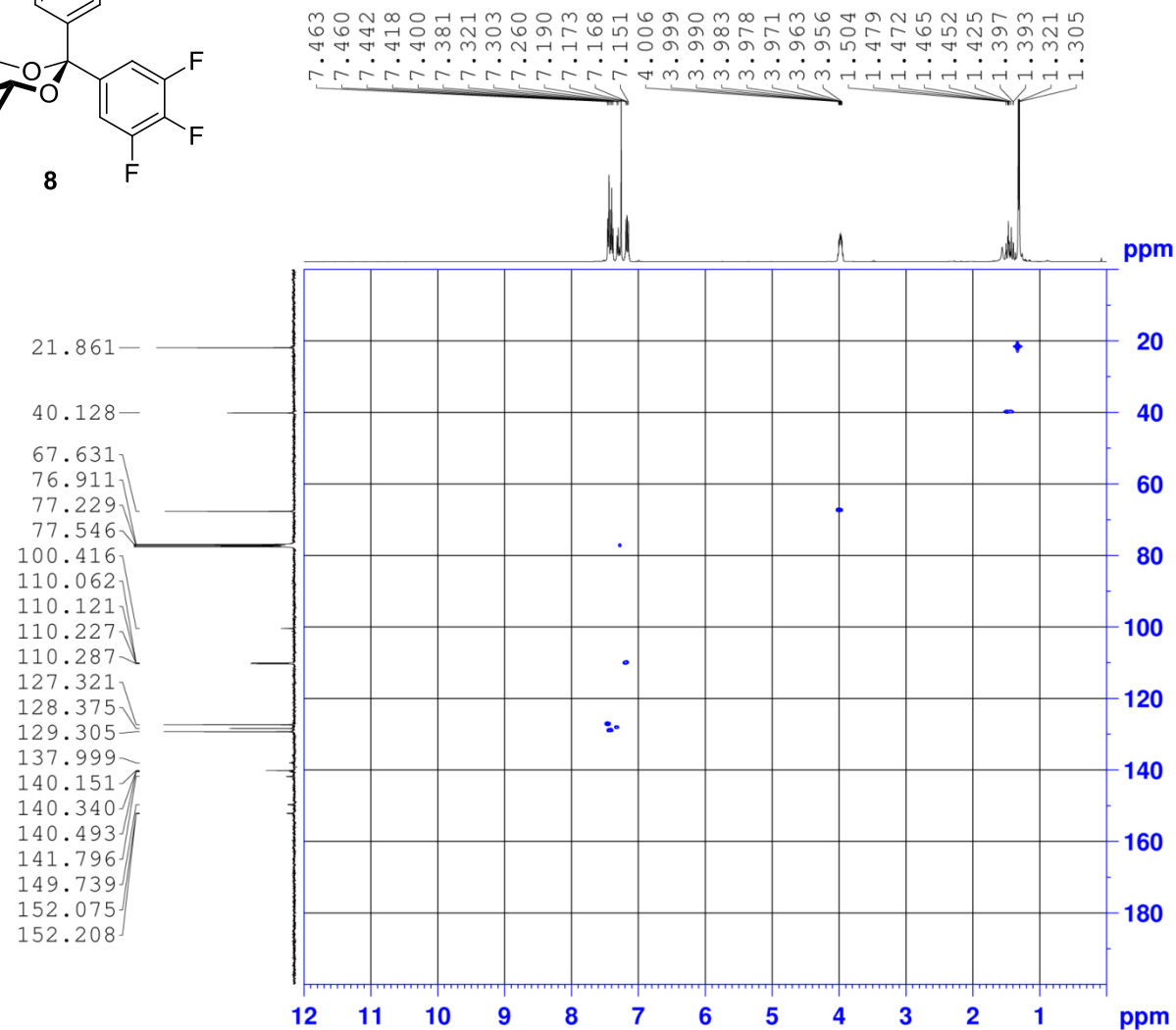
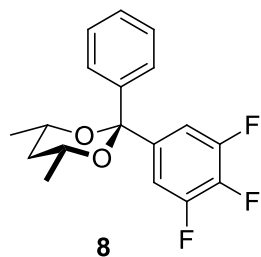
Current Data Parameters
NAME KL-1-45-NOESY-2-processed c
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20130718
Time 20.41
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpgppp
TD 2670
SOLVENT CDCl3
NS 8
DS 32
SWH 8012.820 Hz
FIDRES 3.001056 Hz
AQ 0.1666080 sec
RG 80.6
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
d0 -0.00001842 sec
D1 2.00000000 sec
D8 0.44999999 sec
d11 0.03000000 sec
d12 0.00002000 sec
D16 0.00020000 sec
Ino 0 sec
STICNT 128
TAU 0.22379999 sec
d0orig -0.00001842 sec
philoop 0
t1loop 0
SF01 400.1464009 MHz
NUC1 1H
P1 14.47 usec
p2 28.94 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.71679997 W
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 668
SF01 400.1464 MHz
FIDRES 11.995227 Hz
SW 20.025 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440057 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440058 MHz
WDW USER
SSB 2
LB 0 Hz
GB 0



Current Data Parameters
 NAME kl-83-Middle spot 1-HSQC
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20140214
 Time 0.20
 INSTRUM spect
 PROBHD 5 mm PASBO BB/
 PULPROG hsqcetgp
 TD 1024
 SOLVENT CDCl3
 NS 2
 DS 16
 SWH 5341.880 Hz
 FIDRES 5.216680 Hz
 AQ 0.8958464 sec
 RG 203
 DW 93.600 usec
 DE 6.50 usec
 TE 300.0 K
 CNST2 145.0000000
 d0 0.0000000 sec
 d1 1.5000000 sec
 d4 0.00172414 sec
 d11 0.03000000 sec
 d16 0.00020000 sec
 DELTA 0.00123600 sec
 DELTA1 0.00071919 sec
 in0 0 sec
 STICNT 128
 ZGPTNS
 d0orig 0.00000000 sec
 phloop 0
 t1loop 0
 SFO1 400.1464057 MHz
 NUC1 1H
 P1 15.00 usec
 P2 30.00 usec
 P28 1000.00 usec
 PLW1 12.00000000 W
 SFO2 100.6237933 MHz
 NUC2 13C
 CPDPRG2 garp
 P3 10.00 usec
 P4 20.00 usec
 PCPD2 80.00 usec
 PLW2 50.00000000 W
 PLW12 0.78125000 W
 GPNAM[1] SMSQ10.100
 GPNAM[2] SMSQ10.100
 GPZ1 80.00 %
 GPZ2 20.10 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 100.6238 MHz
 FIDRES 65.106445 Hz
 SW 165.639 ppm
 FMODE Echo-Antiecho

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSI
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.40

F1 - Processing parameters
 SI 1024
 MC2 echo-antiecho
 SF 100.6162890 MHz
 WDW TRAP
 SSB 2
 LB 0 Hz
 GB 0

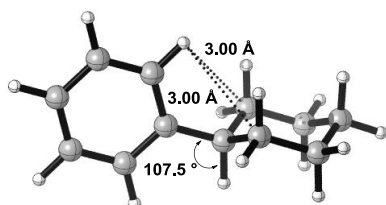
2.2 Rotamers of Phenyl Substituted 1,3-Dioxanes and Tetrahydropyrans: Importance of CH...O Coulombic Interactions¹

AND

The Role of CH...O Columbic Interactions in Determining Rotameric Conformations of Phenyl Substituted 1,3-Dioxanes and Tetrahydropyrans²

Calculated MP2/6-311+G* Ground State Geometries of Compounds 1-12^{3, 4}

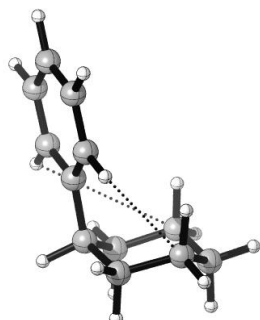
Equatorial Phenylcyclohexane



1

C	2.76212100	0.17078400	1.26255900
C	1.25866600	-0.11495200	1.25974500
C	0.58399700	0.45369100	0.00223000
C	1.25897800	-0.10151000	-1.26111700
C	2.76245600	0.18413400	-1.26042700
C	3.42908300	-0.37481100	-0.00176500
H	1.09407800	-1.20115500	1.29681900
H	0.77921600	0.30429600	2.15295300
H	2.92423600	1.25634300	1.32047400
H	3.22629500	-0.26213400	2.15674000
H	1.09431900	-1.18724900	-1.30984100
H	0.77981700	0.32729000	-2.14993800
H	3.22686800	-0.23931900	-2.15900900
H	2.92463600	1.27023400	-1.30681900
H	3.35055700	-1.47107100	-0.00759000
H	4.49988300	-0.13861600	-0.00038600
H	0.73645400	1.54505100	0.00805500
C	-0.90494200	0.20472400	0.00089600
C	-1.42010000	-1.10400600	-0.00561600
C	-1.81315600	1.27563700	0.00627100
C	-2.80024700	-1.33376000	-0.00665800
H	-0.74073800	-1.95443800	-0.00993200
C	-3.19590300	1.05251300	0.00526500
H	-1.43219600	2.29620900	0.01132400
C	-3.69393400	-0.25513400	-0.00117200
H	-3.17819100	-2.35385800	-0.01169700
H	-3.88072400	1.89768400	0.00956500
H	-4.76662400	-0.43313500	-0.00199200

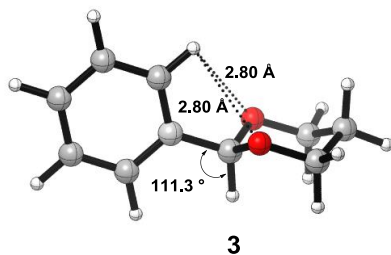
Axial Phenylcyclohexane



2

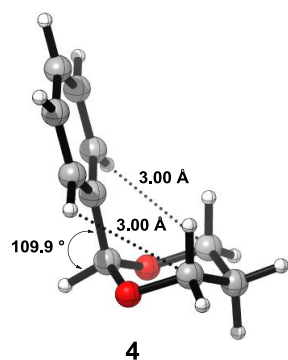
C	-0.70194100	0.33166700	1.08534300
C	-1.60275700	-0.91384900	1.11416100
C	-1.45448500	1.46465100	0.35987400
C	-2.09614200	-1.33664500	-0.27528400
H	-2.47671400	-0.67188400	1.73507300
H	-1.09920000	-1.74433000	1.62260500
C	-1.87915800	1.04840200	-1.04876200
H	-2.34958800	1.71322200	0.94803100
H	-0.85107900	2.37690400	0.32489500
C	-2.79067900	-0.17873700	-0.99487000
H	-2.78158200	-2.18741800	-0.17601000
H	-1.25894100	-1.68086100	-0.89254300
H	-2.38951000	1.88173900	-1.54642500
H	-0.98688000	0.82101000	-1.64750600
H	-3.08459500	-0.48479500	-2.00585700
H	-3.71715500	0.08204200	-0.46381300
H	-0.54405300	0.65061300	2.12722200
C	0.68423300	0.09985800	0.49225700
C	1.17898900	-1.17404500	0.16300600
C	1.55288800	1.19536900	0.32198900
C	2.47251800	-1.34364100	-0.34949000
H	0.56233400	-2.05598400	0.30494100
C	2.84621200	1.03359000	-0.18504500
H	1.22519000	2.19342300	0.60410000
C	3.31096900	-0.24026600	-0.53313700
H	2.82296200	-2.34269400	-0.59985400
H	3.49102200	1.90180800	-0.30283500
H	4.31390500	-0.37091500	-0.93227100

Equatorial 2-Phenyl-1,3-dioxane



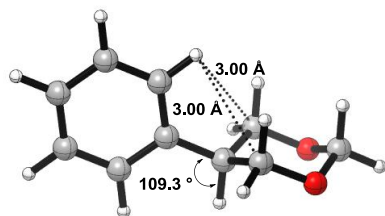
C	0.30193300	2.57705200	1.23474800
C	-0.35552300	0.70657100	0.00000000
C	0.30193300	2.57705200	-1.23474800
C	0.97679800	3.15866600	0.00000000
H	-0.73684800	2.93665100	1.31242200
H	0.82559700	2.83581600	2.15679100
H	0.82559700	2.83581600	-2.15679100
H	-0.73684800	2.93665100	-1.31242200
H	2.03580600	2.88338900	0.00000000
H	0.90431800	4.25293400	0.00000000
H	-1.38756500	1.10867600	0.00000000
C	-0.35627100	-0.79106900	0.00000000
C	-1.55925000	-1.50573100	0.00000000
C	0.86611400	-1.47723000	0.00000000
C	-1.54497500	-2.90602200	0.00000000
H	-2.50740600	-0.97073100	0.00000000
C	0.88015900	-2.87497600	0.00000000
H	1.79399400	-0.91167300	0.00000000
C	-0.32474900	-3.59139400	0.00000000
H	-2.48148600	-3.45860600	0.00000000
H	1.82851900	-3.40727500	0.00000000
H	-0.31161400	-4.67874200	0.00000000
O	0.30193300	1.14997300	1.16923500
O	0.30193300	1.14997300	-1.16923500

Axial 2-Phenyl-1,3-dioxane



C	0.10182900	-1.97809100	1.23073600
C	0.23679900	-2.86166900	0.00000000
C	0.10182900	-1.97809100	-1.23073600
C	-1.24528200	-0.47717700	0.00000000
H	1.20523100	-3.37561100	0.00000000
H	0.94923500	-1.28117000	1.29632200
H	0.05483100	-2.55649100	2.15540000
H	0.94923500	-1.28117000	-1.29632200
H	0.05483100	-2.55649100	-2.15540000
H	-2.28026900	-0.12467700	0.00000000
H	-0.55702900	-3.61493300	0.00000000
C	-0.29276500	0.71378800	0.00000000
C	0.10182900	1.30327200	1.21042900
C	0.10182900	1.30327200	-1.21042900
C	0.92304800	2.43683800	1.21051000
H	-0.22860600	0.86450400	2.14880300
C	0.92304800	2.43683800	-1.21051000
H	-0.22860600	0.86450400	-2.14880300
C	1.33644200	3.00647200	0.00000000
H	1.23056900	2.88099300	2.15452200
H	1.23056900	2.88099300	-2.15452200
H	1.97447300	3.88694900	0.00000000
O	-1.13038200	-1.25125700	1.17630400
O	-1.13038200	-1.25125700	-1.17630400

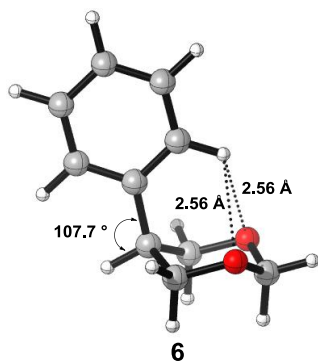
Equatorial 5-Phenyl-1,3-dioxane



5

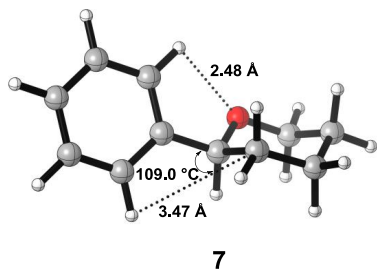
C	-0.39155100	0.69687600	0.00000000
C	0.93230100	3.13872500	0.00000000
H	1.97361300	2.76793000	0.00000000
H	0.90584100	4.22682600	0.00000000
C	-0.37070000	-0.80875300	0.00000000
C	-1.57317600	-1.53547900	0.00000000
C	0.84233900	-1.52204700	0.00000000
C	-1.56935800	-2.93487300	0.00000000
H	-2.51986000	-0.99753500	0.00000000
C	0.84996300	-2.92157400	0.00000000
H	1.79118800	-0.98938000	0.00000000
C	-0.35592800	-3.63247200	0.00000000
H	-2.51145900	-3.47807400	0.00000000
H	1.79735800	-3.45566000	0.00000000
C	0.28626400	1.28794500	-1.23961700
H	-0.24980800	1.01599300	-2.15133600
H	1.32292000	0.92357100	-1.32255500
C	0.28626400	1.28794500	1.23961700
H	1.32292000	0.92357100	1.32255500
H	-0.24980800	1.01599300	2.15133600
O	0.28626400	2.71144900	1.17213900
O	0.28626400	2.71144900	-1.17213900
H	-1.43205000	1.04547300	0.00000000
H	-0.34958600	-4.71963600	0.00000000

Axial 5-Phenyl-1,3-dioxane



C	-0.66209800	-1.07844300	-0.00046100
C	-2.77817500	0.74638800	0.00044600
H	-3.60421700	0.01199000	0.00027100
H	-3.16329100	1.76478400	0.00088000
C	0.70446800	-0.43476300	-0.00025700
C	1.84577200	-1.25634500	-0.00021100
C	0.88415300	0.96144300	-0.00012500
C	3.13363200	-0.70819200	0.00008700
H	1.72605600	-2.33924200	-0.00032500
C	2.17246900	1.50989400	0.00016200
H	0.02000700	1.61596100	-0.00018300
C	3.30068000	0.68099800	0.00021000
H	4.00112300	-1.36432700	0.00009000
H	2.29307900	2.59094600	0.00024600
C	-1.49722600	-0.73340900	1.24068500
H	-0.89639900	-0.78179000	2.15059100
H	-2.33735000	-1.44246700	1.33027100
C	-1.49744800	-0.73245000	-1.24118400
H	-2.33755700	-1.44147300	-1.33117900
H	-0.89678200	-0.78008900	-2.15123600
O	-2.01408000	0.59359800	-1.16830600
O	-2.01380300	0.59271200	1.16891700
H	-0.51746300	-2.16863000	-0.00090200
H	4.29849100	1.11313100	0.00047700

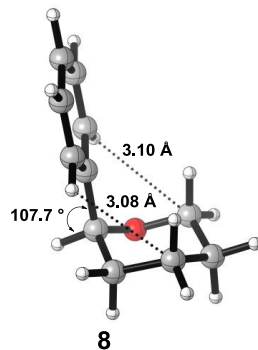
Equatorial 2-Phenyltetrahydropyran



7

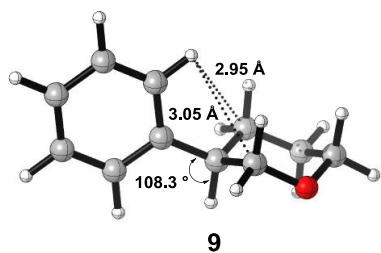
C	-1.31283900	0.54094900	1.16713300
C	-2.82053800	0.28188800	1.14567400
C	-3.33203200	0.29137300	-0.28920100
C	-1.26338700	-0.37651800	-1.16071700
C	-0.60084100	-0.43488300	0.22082100
H	-4.39066500	0.02646700	-0.34299800
H	-3.03989500	-0.69518700	1.59250200
H	-3.35578600	1.03813500	1.73270200
H	-1.11596200	1.57234100	0.84459000
H	-0.90435200	0.44257700	2.17937500
H	-0.82588100	-1.12136400	-1.83077600
H	-1.11246300	0.62066500	-1.60839700
H	-0.75401100	-1.45450500	0.60292000
H	-3.20606000	1.29479500	-0.73000600
O	-2.65244800	-0.66499200	-1.09415000
C	0.88264300	-0.18615600	0.11561500
C	1.80009900	-1.20949600	0.40614300
C	1.38428200	1.06225700	-0.29539700
C	3.17932400	-0.99579400	0.29697200
H	1.42834000	-2.18255800	0.72419500
C	2.76199400	1.28005400	-0.40901500
H	0.69938100	1.87557000	-0.52704900
C	3.66460400	0.25141500	-0.11257700
H	3.87185500	-1.80123400	0.53072600
H	3.13015400	2.25238900	-0.72866500
H	4.73507700	0.42130600	-0.19861900

Axial 2-Phenyltetrahydropyran



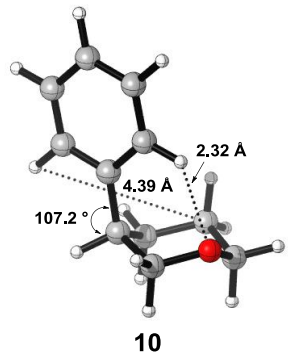
C	0.75356100	-0.08914400	1.10699300
C	1.65918200	1.12216000	0.87615800
C	2.08263900	1.23231800	-0.59009600
H	2.55030400	0.97611800	1.49893000
H	1.17704500	2.03807400	1.23354100
C	1.74365900	-1.23720700	-0.72453000
C	2.69951400	-0.09441800	-1.03657300
H	2.79571400	2.05440000	-0.71790100
H	1.21434000	1.46047600	-1.22007800
H	2.19167000	-2.21019500	-0.94130100
H	0.82667500	-1.14013800	-1.32458600
H	2.92091000	-0.08584600	-2.11069800
H	3.64470800	-0.26527400	-0.50707800
H	0.63801900	-0.24405100	2.18694800
C	-0.64211600	0.01259800	0.50040400
C	-1.24979200	1.23380000	0.16886500
C	-1.38396600	-1.17042600	0.33501500
C	-2.55282300	1.26981400	-0.34623700
H	-0.71369000	2.17050100	0.29498300
C	-2.68313100	-1.13817700	-0.18101400
H	-0.92268200	-2.11933800	0.59858200
C	-3.27479400	0.08488800	-0.52197800
H	-3.00311700	2.22601200	-0.60350300
H	-3.23750300	-2.06567300	-0.30636500
H	-4.28480000	0.11311100	-0.92376300
O	1.41135200	-1.28317600	0.66503100

Equatorial 3-Phenyltetrahydropyran



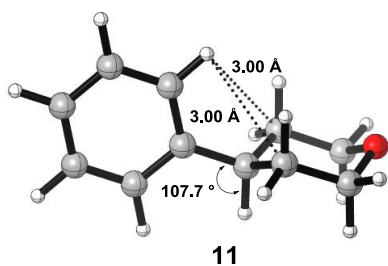
C	-1.31283900	0.54094900	1.16713300
C	-2.82053800	0.28188800	1.14567400
C	-3.33203200	0.29137300	-0.28920100
C	-1.26338700	-0.37651800	-1.16071700
C	-0.60084100	-0.43488300	0.22082100
H	-4.39066500	0.02646700	-0.34299800
H	-3.03989500	-0.69518700	1.59250200
H	-3.35578600	1.03813500	1.73270200
H	-1.11596200	1.57234100	0.84459000
H	-0.90435200	0.44257700	2.17937500
H	-0.82588100	-1.12136400	-1.83077600
H	-1.11246300	0.62066500	-1.60839700
H	-0.75401100	-1.45450500	0.60292000
H	-3.20606000	1.29479500	-0.73000600
O	-2.65244800	-0.66499200	-1.09415000
C	0.88264300	-0.18615600	0.11561500
C	1.80009900	-1.20949600	0.40614300
C	1.38428200	1.06225700	-0.29539700
C	3.17932400	-0.99579400	0.29697200
H	1.42834000	-2.18255800	0.72419500
C	2.76199400	1.28005400	-0.40901500
H	0.69938100	1.87557000	-0.52704900
C	3.66460400	0.25141500	-0.11257700
H	3.87185500	-1.80123400	0.53072600
H	3.13015400	2.25238900	-0.72866500
H	4.73507700	0.42130600	-0.19861900

Axial 3-Phenyltetrahydropyran



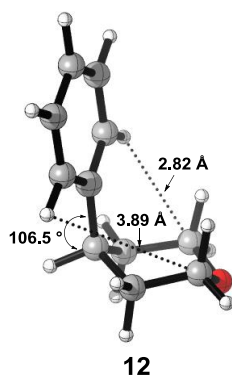
C	-1.38493900	1.46317600	-0.44063200
C	-0.67948200	0.81210100	0.76644400
C	-1.60896200	-0.23697700	1.38088400
C	-2.77829600	-0.59478200	-0.62817400
C	-1.90252700	0.38820300	-1.39472300
H	-1.10105000	-0.79940500	2.16900900
H	-0.53184700	1.58656300	1.53415500
H	-2.23244600	2.06147600	-0.07626000
H	-0.70110300	2.15009100	-0.95107300
H	-3.11793500	-1.41730200	-1.26214200
H	-3.66808900	-0.07964400	-0.22795200
H	-1.06400700	-0.15335500	-1.84688100
H	-2.48197700	0.83785700	-2.21013700
H	-2.47869100	0.27346900	1.82849000
O	-2.06603400	-1.20399800	0.44319400
C	0.69203400	0.29185800	0.38495600
C	1.75033100	1.21416200	0.28927600
C	0.95427600	-1.05647100	0.08433300
C	3.03545300	0.80918600	-0.08463500
H	1.56792500	2.26163300	0.52980000
C	2.24336700	-1.46560500	-0.28452100
H	0.15381000	-1.78760800	0.14600700
C	3.28463000	-0.53652700	-0.38212500
H	3.83801500	1.54096900	-0.14537800
H	2.42811700	-2.51403400	-0.50872500
H	4.28223800	-0.85868000	-0.67095500

Equatorial 4-Phenyltetrahydropyran



C	-0.59105800	-0.46464600	-0.00046900
C	-1.28427000	0.10245500	-1.24730000
C	-2.78733500	-0.13918600	-1.17054100
C	-2.78722100	-0.14131700	1.17038200
C	-1.28416300	0.10021700	1.24740900
H	-3.31049700	0.31997700	-2.01280500
H	-1.10291900	1.18181000	-1.31575400
H	-0.87234300	-0.35789600	-2.15425200
H	-0.74337800	-1.55590800	-0.00145200
H	-3.31030000	0.31630900	2.01353400
H	-2.99882300	-1.22396700	1.18232800
H	-1.10279000	1.17944900	1.31776900
H	-0.87214500	-0.36175100	2.15349900
H	-2.99895000	-1.22181000	-1.18443900
O	-3.35190500	0.43695500	0.00047400
C	0.89627800	-0.20977700	-0.00022400
C	1.80685500	-1.27851600	-0.00103100
C	1.40573700	1.10099000	0.00082500
C	3.18874600	-1.05071500	-0.00080700
H	1.42920900	-2.30030300	-0.00186100
C	2.78512300	1.33460900	0.00106400
H	0.72372500	1.94929200	0.00148500
C	3.68201800	0.25866600	0.00024400
H	3.87633500	-1.89351600	-0.00145200
H	3.15980700	2.35579500	0.00188900
H	4.75404600	0.44020400	0.00041400

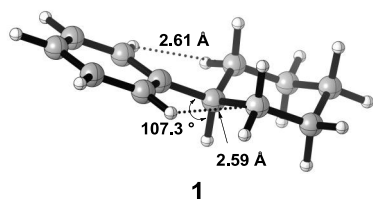
Axial 4-Phenyltetrahydropyran



C	0.69839800	0.40732300	1.03018600
C	1.62061100	-0.81635000	1.14529400
C	2.17254100	-1.26071500	-0.20880700
C	1.94017000	0.87805500	-1.11426200
C	1.43829300	1.47165700	0.19415400
H	2.91862900	-2.04938600	-0.08096300
H	2.47342300	-0.53937000	1.77694300
H	1.11795700	-1.65102700	1.64788900
H	0.55331200	0.81459200	2.04138300
H	2.49994200	1.61568200	-1.69443300
H	1.09540300	0.52455000	-1.72708200
H	2.30414800	1.83511700	0.76147200
H	0.79849500	2.33611500	-0.01142100
H	1.37753500	-1.64600900	-0.86277800
O	2.84216200	-0.19705500	-0.87449700
C	-0.69142900	0.12198000	0.47432400
C	-1.59444400	1.19388900	0.33642600
C	-1.15024100	-1.16150600	0.13388800
C	-2.89395100	0.99963600	-0.14100000
H	-1.28742400	2.19578100	0.63119400
C	-2.44998600	-1.36306000	-0.35149300
H	-0.50453400	-2.02636700	0.24880000
C	-3.32480600	-0.28322700	-0.50084600
H	-3.56792800	1.84853400	-0.23212200
H	-2.77467800	-2.36795500	-0.61237600
H	-4.33251600	-0.43991100	-0.87771200

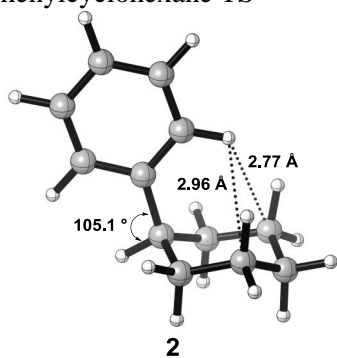
Calculated MP2/6-311+G* Transition State Geometries of Compounds 1-12^{3,4}

Equatorial Phenylcyclohexane TS



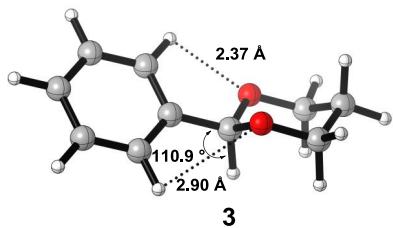
C	2.79178700	-1.25500700	0.11004600
C	1.28039300	-1.25293600	-0.13159200
C	0.59348600	-0.00526700	0.44731000
C	1.28539100	1.25759600	-0.09122400
C	2.79662200	1.24510800	0.15115000
C	3.45041900	0.00331900	-0.44944800
H	1.07614700	-1.29649000	-1.21166000
H	0.85652200	-2.16250900	0.30466300
H	2.98498700	-1.31600800	1.19035800
H	3.23368800	-2.15376900	-0.33645400
H	1.08253900	1.33891400	-1.16935900
H	0.86508600	2.15327300	0.37664600
H	3.24260300	2.15634100	-0.26497600
H	2.98941000	1.26938500	1.23298400
H	3.33672600	0.02145600	-1.54218600
H	4.52766800	-0.00212700	-0.24482900
H	0.74352600	-0.01834700	1.54099000
C	-0.91372300	-0.00012100	0.19666900
C	-1.63909100	1.20204500	0.08986200
C	-1.64678700	-1.20075000	0.12566500
C	-3.02487900	1.20622900	-0.11108900
H	-1.12894600	2.15828600	0.14545100
C	-3.03246300	-1.20267100	-0.07392100
H	-1.14284600	-2.15784800	0.21492200
C	-3.73190300	0.00262000	-0.19072700
H	-3.55059300	2.15491000	-0.19576500
H	-3.56427300	-2.15013500	-0.12888300
H	-4.80775200	0.00367200	-0.34811100

Axial Phenylcyclohexane TS



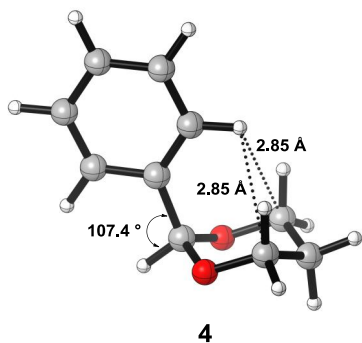
C	-0.60784300	-1.05124800	0.24398700
C	-1.38214800	-1.04286300	-1.09113400
C	-1.49653000	-0.53012500	1.39274900
C	-2.07521800	0.28801400	-1.38554100
H	-2.15108800	-1.82812800	-1.04253500
H	-0.70261900	-1.31759700	-1.90681600
C	-2.26048600	0.76370300	1.09088200
H	-2.23703000	-1.31391400	1.60974000
H	-0.89076000	-0.41666100	2.29985800
C	-3.01241000	0.67448500	-0.23906900
H	-2.64009300	0.20437800	-2.32185400
H	-1.32997600	1.07563800	-1.54887600
H	-2.96650200	0.95766200	1.90779400
H	-1.58053100	1.62186300	1.07727600
H	-3.51456800	1.62493700	-0.45569800
H	-3.80390300	-0.08406800	-0.15581800
H	-0.39871900	-2.10469500	0.47548900
C	0.75456800	-0.39462600	0.13220100
C	0.96456000	0.99364400	0.02080100
C	1.89252300	-1.22395300	0.11505800
C	2.25534300	1.52378600	-0.10365600
H	0.12664600	1.68059800	0.02906100
C	3.18437600	-0.70162200	-0.01221400
H	1.76179400	-2.30166300	0.20484000
C	3.37149200	0.68055900	-0.12192100
H	2.38549400	2.60077700	-0.18605100
H	4.04046300	-1.37269600	-0.02058100
H	4.37203200	1.09504900	-0.21868700

Equatorial 2-Phenyl-1,3-dioxane TS



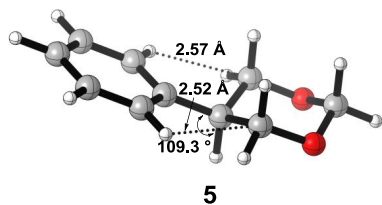
C	-2.64539000	1.04271100	0.57643400
C	-0.64603200	-0.14037700	0.41519200
C	-2.54654300	-1.22430400	-0.40008900
C	-3.28098100	0.10855900	-0.44381100
H	-2.82355200	0.67807100	1.60065000
H	-3.02692800	2.06264800	0.50263900
H	-2.85445400	-1.89534700	-1.20380800
H	-2.72095900	-1.73026300	0.56337100
H	-3.18384000	0.54303500	-1.44314300
H	-4.34717800	-0.02920100	-0.22786800
H	-0.87695300	-0.58158600	1.40600600
C	0.83928700	-0.02596200	0.21293100
C	1.63655100	-1.15024100	0.46907400
C	1.42701600	1.15358500	-0.25951200
C	3.01852800	-1.09445200	0.26350700
H	1.17324200	-2.06977700	0.82200800
C	2.81152500	1.20814800	-0.46198100
H	0.80299400	2.01979500	-0.45561700
C	3.60862700	0.08627000	-0.20572000
H	3.63251700	-1.96931900	0.46412700
H	3.26679300	2.12612500	-0.82653900
H	4.68341500	0.13283700	-0.36446000
O	-1.23839700	1.13307000	0.34817200
O	-1.14418000	-1.01690100	-0.57736200

Axial 2-Phenyl-1,3-dioxane TS



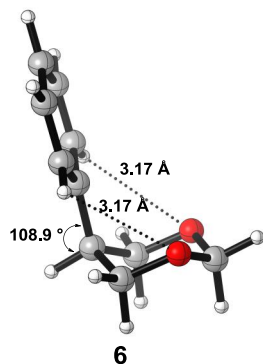
C	-2.07790100	0.46787800	-1.24273700
C	-2.92894500	0.69048100	0.00038400
C	-2.07764900	0.46702400	1.24312500
C	-0.68339800	-1.03071600	-0.00036600
H	-3.35454900	1.70113000	0.00076600
H	-1.33809400	1.26651200	-1.37728800
H	-2.69024000	0.42980400	-2.14584500
H	-1.33736600	1.26514600	1.37788900
H	-2.68964300	0.42866000	2.14645300
H	-0.52011300	-2.11038700	-0.00086000
H	-3.75461600	-0.02812900	0.00028500
C	0.68622500	-0.36404200	0.00006300
C	0.94280900	1.02169000	0.00003100
C	1.79091800	-1.23449400	-0.00025200
C	2.25680500	1.50574000	0.00043500
H	0.13899400	1.74706200	0.00044900
C	3.10416200	-0.75412300	0.00013700
H	1.61972400	-2.30936300	-0.00032000
C	3.34247100	0.62377100	-0.00005300
H	2.42864600	2.57972100	0.00022000
H	3.93589100	-1.45456800	-0.00007700
H	4.35999200	1.00667600	0.00016500
O	-1.43305200	-0.80451500	-1.17997400
O	-1.43340000	-0.80567500	1.17916900

Equatorial 5-Phenyl-1,3-dioxane TS



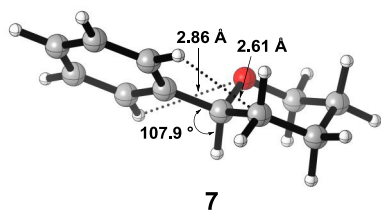
C	0.62747800	0.00383700	-0.49955600
C	3.24379500	-0.00334700	0.43320800
H	3.03747500	-0.00269100	1.51914100
H	4.31489200	-0.00633300	0.23980300
C	-0.85704500	0.00797300	-0.24751200
C	-1.56039300	-1.20249500	-0.12857400
C	-1.57342900	1.21302000	-0.12540900
C	-2.94000100	-1.21421200	0.10565100
H	-1.01977200	-2.14315000	-0.22073100
C	-2.95321000	1.20510800	0.10884700
H	-1.05863200	2.16772300	-0.21243600
C	-3.64091700	-0.00860000	0.22512800
H	-3.46525700	-2.16228400	0.19445600
H	-3.49003600	2.14651600	0.20036000
C	1.31227400	-1.23763900	0.07944100
H	0.95862300	-2.14841900	-0.40838600
H	1.11135300	-1.31993700	1.15979300
C	1.31915000	1.24158500	0.07925000
H	1.11868900	1.32516300	1.15959000
H	0.97055600	2.15423700	-0.40871700
O	2.72554200	1.17019000	-0.13956100
O	2.71904100	-1.17407900	-0.13938100
H	0.81198900	0.00324200	-1.58127400
H	-4.71274700	-0.01432700	0.40710100

Axial 5-Phenyl-1,3-dioxane TS



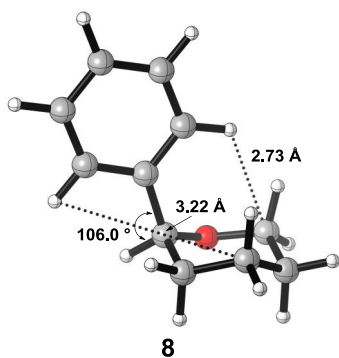
C	0.76539900	-0.04877100	1.09244500
C	2.57033600	0.03320800	-1.03922500
H	3.54036800	0.00314300	-0.51031600
H	2.71318800	0.07892300	-2.11714300
C	-0.63694400	-0.01588800	0.49307900
C	-1.30050500	1.19820700	0.24463300
C	-1.34827600	-1.20535700	0.25528400
C	-2.61055100	1.22435600	-0.24792700
H	-0.79711700	2.14660900	0.40364500
C	-2.65853900	-1.18550500	-0.23586300
H	-0.88592400	-2.17107800	0.43576400
C	-3.29930100	0.03155100	-0.48834600
H	-3.09102400	2.18115400	-0.43954400
H	-3.17711900	-2.12438600	-0.41642000
C	1.59272800	-1.25095300	0.62555900
H	1.09727100	-2.20904100	0.77728800
H	2.54284600	-1.27516700	1.18438200
C	1.61058600	1.17726700	0.73090300
H	2.56046200	1.13587900	1.28915700
H	1.13002000	2.12459700	0.97280600
O	1.87700500	1.19838300	-0.66633900
O	1.85926600	-1.14896700	-0.76867200
H	0.68314100	-0.08455900	2.19058600
H	-4.31587600	0.04991400	-0.87337500

Equatorial 2-Phenyltetrahydropyran TS



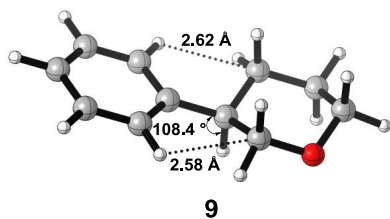
C	2.47928600	-1.29514000	-0.36404900
C	0.61914100	-0.06886800	0.41243400
C	1.38035100	1.25069800	0.34903000
C	2.87716100	0.99700600	0.54609900
C	3.35804000	-0.05500300	-0.45423000
H	2.59365200	-1.77254700	0.62381600
H	2.73534500	-2.03048500	-1.13060800
H	1.21449600	1.70954800	-0.63277300
H	0.99354700	1.93750600	1.11141100
H	3.44219500	1.92882600	0.43409100
H	3.05537100	0.63961000	1.56948700
H	3.29892100	0.34405200	-1.47374600
H	4.40382400	-0.32888700	-0.26875800
H	0.80263800	-0.52402300	1.40508300
C	-0.87506400	0.01880600	0.21099000
C	-1.64441700	-1.12256700	0.49182400
C	-1.51807800	1.16279000	-0.28241900
C	-3.02833600	-1.12006400	0.29765500
H	-1.14680700	-2.01902100	0.85750600
C	-2.90696600	1.17221400	-0.46924800
H	-0.94948400	2.05981800	-0.51074000
C	-3.66428100	0.03059500	-0.18705300
H	-3.60936800	-2.01222300	0.51985200
H	-3.39372300	2.06837900	-0.84739000
H	-4.74135400	0.03877800	-0.33643900
O	1.10496500	-0.98276600	-0.57837500

Axial 2-Phenyltetrahydropyran TS



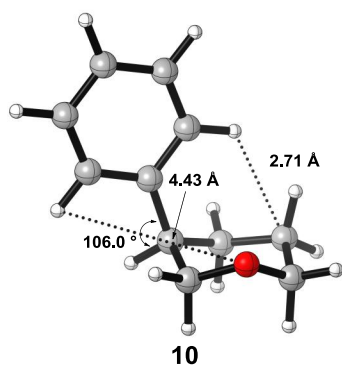
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C	2.04106900	0.06386100	-1.41891800
H	2.13558700	2.01797300	-0.53474600
H	0.64696500	1.74428900	-1.44900400
C	2.24738800	-0.93513700	0.86108500
C	3.00287800	-0.54695700	-0.40159800
H	2.57533900	0.37064300	-2.32454200
H	1.28991700	-0.67404200	-1.72865200
H	2.93679900	-1.21218100	1.66286500
H	1.61407000	-1.80938000	0.66429200
H	3.50583600	-1.43558100	-0.80164300
H	3.78137300	0.18396900	-0.15053900
H	0.47830900	1.81603700	1.09795500
C	-0.73161200	0.30552600	0.27170200
C	-0.99396800	-1.04657300	-0.00869300
C	-1.81923800	1.19771200	0.28408900
C	-2.29684200	-1.48332200	-0.28177000
H	-0.19442200	-1.77734400	-0.01538800
C	-3.12003300	0.76937800	0.00072500
H	-1.64381700	2.24624500	0.52281300
C	-3.36423900	-0.57925100	-0.28232200
H	-2.47514700	-2.53581100	-0.49084400
H	-3.94100300	1.48252700	0.01962200
H	-4.37374500	-0.92228700	-0.49519000
O	1.47467600	0.13114500	1.41560800

Equatorial 3-Phenyltetrahydropyran TS



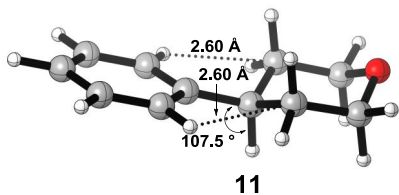
C	1.30418900	1.26714700	0.12213500
C	2.82079600	1.19272200	-0.06356000
C	3.34908700	-0.13696400	0.44796100
C	1.30979000	-1.22397500	0.04900900
C	0.61197400	0.03502200	-0.48147500
H	4.41649000	-0.25668300	0.24760200
H	3.07213100	1.28427900	-1.12687000
H	3.31321900	2.01974300	0.46225200
H	1.06029600	1.31921600	1.19317700
H	0.92790700	2.18717900	-0.33466300
H	0.93986500	-2.12630500	-0.43969800
H	1.12886300	-1.31738500	1.13405700
H	0.77376700	0.05233200	-1.57094900
H	3.19071200	-0.22133700	1.53603800
O	2.70584800	-1.22006100	-0.20982600
C	-0.88886400	0.01271900	-0.21875000
C	-1.60020200	-1.19677900	-0.09829400
C	-1.62614100	1.20905200	-0.13669900
C	-2.98255400	-1.20961800	0.12522300
H	-1.08632200	-2.15068100	-0.16586700
C	-3.00869300	1.20080100	0.08105500
H	-1.12628700	2.16789000	-0.23533300
C	-3.69599600	-0.01032100	0.21218800
H	-3.50057000	-2.16132400	0.22055500
H	-3.54778000	2.14372200	0.14076100
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Axial 3-Phenyltetrahydropyran TS



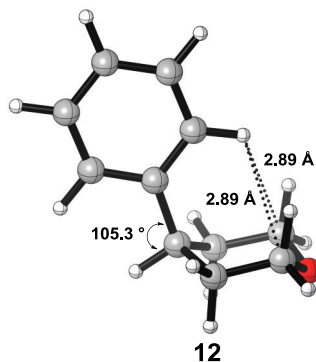
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C	-1.35007100	-1.34842000	-0.55045000
C	-2.90276100	0.38010700	-0.70322700
C	-2.35565100	1.13093000	0.50211100
H	-0.65640400	-1.92305000	-1.16926600
H	-0.48311300	-1.65035200	1.36685100
H	-2.32119300	-0.42695900	1.97469700
H	-1.02727400	0.74287800	2.18778400
H	-3.33728900	1.06184500	-1.43820000
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H	-1.72296800	1.94637800	0.14346300
H	-3.18325300	1.59563000	1.05268900
H	-2.17406900	-2.01376100	-0.23818900
O	-1.86872200	-0.32316400	-1.38042300
C	0.73722500	-0.26914700	0.35339400
C	1.80258600	-1.18899000	0.32692500
C	1.01611500	1.06605400	0.02020100
C	3.09773200	-0.79827400	-0.02684200
H	1.61422600	-2.22853900	0.59487900
C	2.31321800	1.46618900	-0.32716500
H	0.22717600	1.80911400	0.02683900
C	3.35805100	0.53695300	-0.35760900
H	3.90102200	-1.53160900	-0.03675700
H	2.50289200	2.50697800	-0.58033300
H	4.36313900	0.84973300	-0.62989700

Equatorial 4-Phenyltetrahydropyran TS



C	-0.60094400	-0.00012000	0.45313400
C	-1.30346600	-1.24217600	-0.11398400
C	-2.81128000	-1.16304200	0.09193900
C	-2.81137000	1.16304600	0.09222600
C	-1.30343000	1.24212900	-0.11355000
H	-3.31639700	-2.01151200	-0.37584200
H	-1.08855800	-1.32372100	-1.18717400
H	-0.94224200	-2.15857500	0.36557600
H	-0.75616800	-0.00031700	1.54598500
H	-3.31641600	2.01162600	-0.37542200
H	-3.04711600	1.17546000	1.16993400
H	-1.08851500	1.32398100	-1.18671700
H	-0.94219800	2.15837700	0.36628700
H	-3.04694200	-1.17571600	1.16966400
O	-3.37019600	0.00005900	-0.49889600
C	0.90265800	0.00001500	0.20380500
C	1.62724300	-1.20294800	0.11121400
C	1.62711600	1.20291900	0.11094400
C	3.01280600	-1.20564000	-0.08950300
H	1.11595700	-2.15823000	0.18211300
C	3.01269700	1.20570800	-0.08981100
H	1.11575500	2.15818500	0.18154600
C	3.71459200	0.00006600	-0.18842800
H	3.54235300	-2.15302600	-0.16257800
H	3.54211400	2.15314800	-0.16314100
H	4.79020700	0.00011000	-0.34697900

Axial 4-Phenyltetrahydropyran TS



C	-0.61280700	1.04814700	-0.00026900
C	-1.45445700	0.75058400	-1.25971700
C	-2.23636700	-0.55471500	-1.17053900
C	-2.23626600	-0.55410900	1.17088500
C	-1.45440900	0.75124700	1.25936400
H	-2.92817900	-0.64351000	-2.01203500
H	-2.18366900	1.56124400	-1.38414600
H	-0.81545500	0.74528000	-2.15102600
H	-0.42284800	2.12904100	-0.00058100
H	-2.92800500	-0.64257000	2.01247300
H	-1.56984300	-1.42811700	1.19757300
H	-2.18366900	1.56191900	1.38341700
H	-0.81537600	0.74641500	2.15065400
H	-1.57000000	-1.42877300	-1.19693300
O	-3.04434400	-0.60076100	0.00020700
C	0.75865500	0.40114700	-0.00003500
C	1.88984300	1.23941600	-0.00024400
C	0.98308000	-0.98955400	-0.00005500
C	3.19027700	0.72237100	0.00007600
H	1.74769000	2.31924500	-0.00033500
C	2.28202000	-1.51357500	0.00027700
H	0.15186400	-1.68492300	0.00011900
C	3.39192500	-0.66185100	0.00004000
H	4.04107700	1.40003600	-0.00014100
H	2.42324400	-2.59219500	0.00019300
H	4.39896900	-1.07165600	0.00041500

Discussion on Atomic Charges

These charges are not quantum chemically defined and are derived from either the molecular orbitals or the electron density distribution. The earliest is the Mulliken Population (Mulliken, R. S. *J. Chem. Phys.* **1955**, 23, 1841) and is based on molecular orbitals. A major problem is its basis set dependence: with methane the H population is 0.2335 using MP2/aug.cc.pVTZ whereas with MP2/aug.cc.pVDZ it is 0.1465. The Natural Population Analysis (Reed, A. E.; Weinstock, R. B.; Weinhold, R. J. *J. Chem. Phys.* **1985**, 83, 1735) is much more satisfactory and here the corresponding H charges are 0.2042 and 0.2096. They have been recognized as being too large (Reed, A. E.; Weinhold, F. *J. Chem. Phys.* **1986**, 84, 2428). The Hirshfeld charges are derived from the electron density distribution. Here, a promolecule is created with spherically symmetrical atoms placed at the locations in the real molecule. Then, for any point about the real molecule and its charge density, a corresponding point is located about the promolecule, and the charge density from each of the proatoms is determined. The value for the real molecule is divided into contributions from its atoms in accordance with the charge components from the atoms of the promolecule. Finally, the amounts in the "charge buckets" for the real molecule atoms are summed. The charges thus determined have little basis set dependence, and since they are derived based on spherically symmetrical atoms in each case, this facilitates comparisons between molecules. For methane, the calculated H charges are 0.0396 and 0.0351 respectively. The values become more positive when attached to an alkene or alkyne as a result of the increased s character of the C orbital.

Calculated MP2/6-311+G* Energies³

Compound	State	τ	$\mu(D)$	E(0)	E(298)	H(298)	$\Delta E(0)$	$\Delta E(298)$	$\Delta H(298)$
ax-Phenylcyclohexane (2)	gs	66.5	0.451	-465.21243	-465.20219	-465.20124	3.39	3.24	3.24
11.5i	ts	10.0	0.437	-465.21064	-465.20110	-465.20016	1.12	0.68	0.68
Eq-Phenylcyclohexane (1)	gs	0.0	0.530	-465.21783	-465.20735	-465.20641			
66.1i	ts	90.0	0.649	-465.21189	-465.20234	-465.20140	3.73	3.14	3.14
ax-2-Phenyldioxane (4)	gs	87.5	2.460	-537.028075	-537.018425	-537.017481	1.31	1.14	1.13
22.3i	gs	0.0	2.331	-537.017476	-537.008395	-537.007451	6.65	6.29	6.29
eq-2-Phenyldioxane (3)	gs	0.0	2.457	-537.030167	-537.020234	-537.019289			
23.9i	ts	49.5	2.609	-537.029635	-537.020640	-537.019696	0.33	-0.25	-0.26
ax-5-Phenyldioxane (6)	gs	0.0	2.303	-537.026744	-537.016935	-537.015991	0.89	0.83	0.83
69.0i	ts	90.0	2.315	-537.020184	-537.011427	-537.010483	4.12	3.46	3.46
eq-5-Phenyldioxane (5)	gs	0.0	2.483	-537.028167	-537.018261	-537.017317			
56.6 i	ts	90.0	2.402	-537.022943	-537.013982	-537.019040	3.28	2.69	2.68
ax-2-PhenylTHP (8)	gs	100.3	1.584	-501.117935	-501.107970	-501.107025	2.34	2.19	2.19
48.2i	ts	24.2	1.793	-501.110486	-501.101068	-501.100123	4.67	4.33	4.33
eq-2-PhenylTHP (7)	gs	27.9	1.877	-501.121668	-501.111457	-501.110512			
21.4i	ts	134.6	1.793	-501.118071	-501.108790	-501.107846	2.26	1.67	1.67
ax-3-PhenylTHP (10)	gs	143.3	1.774	-501.118325	-501.108261	-501.107306	0.81	0.71	0.72
45.7i	ts	39.0	1.832	-501.112749	-501.103455	-501.102511	3.50	3.02	3.01
eq-3-PhenylTHP (9)	gs	3.7	1.667	-501.119611	-501.109399	-501.108455			
59.3i	ts	90.0	1.614	-501.113966	-501.104684	-501.103740	3.54	2.96	2.96
ax-4-PhenylTHP (12)	gS	60.7	1.626	-501.114134	-501.104126	-501.103182	3.65	3.53	3.53
22.1i	Ts	0.0	1.566	-501.112062	-501.102776	-501.101832	1.30	0.85	0.85
eq-4-PhenylTHP (11)	gs	0.0	1.504	-501.119948	-501.109752	-501.108808			
56.8i	ts	90.9	1.494	-501.115123	-501.105874	-501.104930	3.03	2.43	2.43

References Chapter II Section 2.2

¹ Wiberg, K. B.; Lambert, K. M.; Bailey, W. F. *Tetrahedron Lett.* **2015**, 56, 3438–3440.

² Wiberg, K. B.; Lambert, K. L.; Bailey, W. F. *J. Org. Chem.* **2015**, 80, 7884.

³ Gaussian 09 Revision D.01, Frisch, M. J.; Trucks, G. W.; Schlegel, H. B.; Scuseria, G. E.; Robb, M. A.; Cheeseman, J. R.; Scalmani, G.; Barone, V.; Mennucci, B.; Petersson, G. A.; Nakatsuji, H.; Caricato, M.; Hratchian, H. P.; Li, X.; Izmaylov, A. F.; Bloino, J.; Zheng, G.; Sonnenberg, J. L.; Hada, M.; Ehara, M.; Toyota, K.; Fukuda, R.; Hasegawa, J.; Ishida, M.; Nakajima, T.; Honda, Y.; Kitao, O.; Nakai, H.; Vreven, T.; Montgomery, Jr., J. A.; Peralta, J. E.; Ogliaro, F.; Bearpark, M.; Heyd, J. J.; Brothers, E.; Kudin, K. N.; Staroverov, V. N.; Kobayashi, R.; Normand, J.; Raghavachari, K.; Rendell, A.; Burant, J. C.; Iyengar, S. S.; Tomasi, J.; Cossi, M.; Rega, N.; Millam, J. M.; Klene, M.; Knox, J. E.; Cross, J. B.; Bakken, V.; Adamo, C.; Jaramillo, J.; Gomperts, R.; Stratmann, R. E.; Yazyev, O.; Austin, A. J.; Cammi, R.; Pomelli, C.; Ochterski, J. W.; Martin, M. L.; Morokuma, K.; Zakrzewski, V. G.; Voth, G. A.; Salvador, P.; Dannenberg, J. J.; Dapprich, S.; Daniels, A. D.; Farkas, O.; Foresman, J. B.; Ortiz, J. V.; Cioslowski, J.; Fox, D. J. Gaussian, Inc., Wallingford, CT 2009.

⁴ Legault, C. Y, Université de Sherbrook, 2009. (<http://www.cylview.org>).

2.3 Controlling the Conformational Energy of a Phenyl Group by Tuning the Strength of a Non-Classical CH...O Hydrogen Bond: The Case of 5-Phenyl-1,3-dioxane¹

General Procedures

Anhydrous solvents were obtained as follows: dry Et₂O and THF were freshly distilled from a dark-purple solution of sodium and benzophenone; cyclohexane was dried over anhydrous magnesium sulfate, filtered, and freshly distilled from a dark blue solution of sodium/benzophenone/tetraglyme; acetonitrile was distilled from calcium hydride; dry CHCl₃ was obtained by stirring with anhydrous potassium carbonate then passage through a short column of activated alumina. Reactions involving organometallic reagents were conducted in flame-dried glassware under an argon atmosphere using standard techniques for handling air sensitive reagents,² solvents were deoxygenated by bubbling dry argon gas through the neat liquid for 10 minutes before use, and *t*-butyllithium was titrated immediately prior to use utilizing the method of Watson and Eastham.³ Sodium hydride, purchased as a 60% dispersion in mineral oil, was washed with pentane to remove the mineral oil coating prior to use. NMR spectra were recorded in CDCl₃ on a 400 or 500 MHz spectrometer, and chemical shifts are reported in ppm. Proton spectra are referenced to the residual ¹H signal of CHCl₃ at $\delta = 7.26$ and are reported relative to TMS at $\delta = 0.00$; carbon spectra are referenced to the ¹³C signal for CDCl₃ at $\delta = 77.23$ and are reported relative to TMS at $\delta = 0.00$; fluorine spectra are referenced to a fluorobenzene internal standard at $\delta = -113.15$ and are reported relative to CCl₃F at $\delta = 0.00$. Residual acid present in the CDCl₃ NMR solvent was neutralized with the addition of and storage over anhydrous potassium carbonate to prevent epimerization of products. HRMS molecular mass determinations were performed on a TOF mass spectrometer using a direct analysis in real time (DART) ionization method. Refractive indices and melting points are uncorrected. All numbered compounds in this section originate from Chart 1-2 above.

Synthesis of Ethyl Esters

Ethyl 2-(4-chlorophenyl)acetate.⁴ Following the general method of Xu and co-workers,⁵ 100 mL of absolute ethanol was added to a 250 mL round-bottomed flask containing a magnetic stir bar

followed by the addition of 21.32 g (125.0 mmol) of 4-chlorophenylacetic acid and 9.80 mL (138 mmol) of acetyl chloride. The flask was fitted with a condenser and heated in an oil bath to 50 °C for 1.5 h then allowed to cool to room temperature. Solvent was removed under reduced pressure, the residue was taken up in 100 mL of Et₂O and washed with saturated aqueous NaHCO₃ (3 x 50 mL), brine (1 x 25 mL), dried over Na₂SO₄ and concentrated to afford 22.62 g (91%) of the title compound as a light yellow oil: ¹H NMR (400 MHz, CDCl₃) δ 1.26 (t, *J* = 7.1 Hz, 3H), 3.59 (s, 2H), 4.16 (q, *J* = 7.0 Hz, 2H), 7.23 (d, *J* = 8.2 Hz, 2H), 7.29 (d, *J* = 8.2 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 14.3, 40.8, 61.1, 128.8, 130.7, 132.7, 133.1, 171.2.

Ethyl 2-(4-methoxyphenyl)acetate.⁶ Following the representative procedure, 20.77 g (125.0 mmol) of 4-methoxyphenylacetic acid yielded 23.51 g (97%) of the title compound as a light yellow oil: *n*_D²¹ = 1.5080 (lit.⁷ *n*_D²⁰ = 1.5064); ¹H NMR (400 MHz, CDCl₃) δ 1.24 (t, *J* = 7.2 Hz, 3H), 3.55 (s, 2H), 3.76 (s, 3H), 4.14 (q, *J* = 7.1 Hz, 2H), 6.86 (d, *J* = 8.5 Hz, 2H), 7.20 (d, *J* = 8.5 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 14.2, 40.5, 55.1, 60.7, 113.9, 126.3, 130.2, 158.7, 171.8.

Ethyl 2-(4-trifluoromethylphenyl)acetate.⁸ Following the representative procedure, 20.42 g (100.0 mmol) of 4-trifluoromethylphenylacetic acid gave 21.47 g (93%) of the title compound as a white crystalline solid: mp 37.1 – 38.2 °C (ethanol) (lit.⁹ mp 34 – 35 °C); ¹H NMR (400 MHz, CDCl₃) δ 1.26 (t, *J* = 7.2 Hz, 3H), 3.67 (s, 2H), 4.17 (q, *J* = 7.2 Hz, 2H), 7.41 (d, *J* = 8.1 Hz, 2H), 7.58 (d, *J* = 8.1 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 14.3, 41.3, 61.3, 124.3 (q, *J*_{C-F} = 272 Hz), 125.6 (q, *J*_{C-F} = 3.7 Hz), 129.6 (q, *J*_{C-F} = 32.5 Hz), 129.9, 138.3, 171.0; ¹⁹F NMR (376 MHz, CDCl₃) δ –62.6.

Ethyl 2-(3,5-bis(trifluoromethyl)phenyl)acetate.¹⁰ Following the representative procedure, 34.02 g (125.0 mmol) of 3,5-bis(trifluoromethyl)phenylacetic acid afforded 31.42 g (84%) of the title compound as a light-yellow oil: *n*_D²¹ = 1.4239; ¹H NMR (400 MHz, CDCl₃) δ 1.26 (t, *J* = 7.2 Hz, 3H), 3.74 (s, 2H), 4.18 (q, *J* = 7.2 Hz, 2H), 7.76 (s, 2H), 7.79 (s, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 14.1, 40.8, 61.6, 121.5 (septet, *J*_{C-F} = 3.8 Hz), 123.5 (q, *J*_{C-F} = 272 Hz), 129.9 (q, *J*_{C-F} = 3.7 Hz), 132.0 (q, *J*_{C-F} =

33.2 Hz), 136.8, 170.1; ^{19}F NMR (376 MHz, CDCl_3) δ -63.0; HRMS (DART-TOF) m/z calcd for $\text{C}_{12}\text{H}_{10}\text{F}_6\text{O}_2$ $[\text{M} + \text{H}]^+$ 301.0663, found 301.0677.

Ethyl 2-(4-bromophenyl)acetate.⁶ Following the representative procedure, 16.58 g (77.0 mmol) of 4-bromophenylacetic acid gave 16.55 g of the title compound as a clear, colorless oil that crystallized upon standing: mp 30.5 – 31.4 °C (ethanol) (lit.¹¹ mp 31 – 34 °C); ^1H NMR (400 MHz, CDCl_3) δ 1.24 (t, J = 7.2 Hz, 3H), 3.55 (s, 2H), 4.14 (q, J = 7.2 Hz, 2H), 7.15 (d, J = 8.3 Hz, 2H), 7.43 (d, J = 8.3 Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 14.2, 40.8, 61.1, 121.1, 131.1, 131.7, 133.2, 171.0.

Synthesis of Diethyl Arylmalonates

Diethyl (4-bromophenyl)malonate.⁶ Following the general method of Enoua and co-workers with minor modifications,¹² a dry 250 mL round-bottomed flask containing a magnetic stir bar was flushed with dry nitrogen and charged with 5.92 g (246.9 mmol) of oil-free sodium hydride, 150 mL of anhydrous THF and 36.47 g (308.7 mmol) of diethyl carbonate. Carefully, 15.01 g (61.7 mmol) of ethyl 2-(4-bromophenyl)acetate in 40 mL of anhydrous THF was added dropwise over a period of 10 min. The flask was then fitted with a condenser and the reaction mixture was heated at reflux. The reaction progress was monitored colorimetrically; the initial off-white solution developed a bright orange color over the course of the reaction, and upon persistence of this color (*ca.* 4 h for most substrates) the reaction was cooled to room temperature. An ice-water bath was placed under the reaction flask and saturated, aqueous ammonium chloride was added dropwise through the condenser until the evolution of hydrogen gas ceased. The mixture was then poured into a 500 mL separatory funnel and 100 mL of Et_2O was added. The organic layer was collected and the aqueous layer was extracted with Et_2O (2 x 75 mL). The combined organic layers were rinsed with saturated, aqueous ammonium chloride (2 x 75 mL), saturated, aqueous NaHCO_3 (2 x 75 mL), brine (1 x 50 mL), dried over Na_2SO_4 , and concentrated. The resulting orange oil was distilled (Kugelrohr, bath temperature = 195 °C, 20 mm) to yield 17.50 g (90%) of the title compound as a colorless oil: n_D^{23} = 1.515; ^1H NMR (400 MHz, CDCl_3) δ 1.25 (t, J = 7.2 Hz, 6H), 4.14–

4.27 (m, 4H), 4.56 (s, 1H), 7.28 (d, $J = 8.5$ Hz, 2H), 7.48 (d, $J = 8.5$ Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 14.1, 57.5, 62.1, 122.6, 131.2, 131.9, 132.0, 167.8.

Diethyl 2-(4-trifluoromethylphenyl)malonate.¹³ Following the representative procedure with minor modification, 10.00 g (43.0 mmol) of ethyl 2-(4-trifluoromethylphenyl)acetate afforded a light orange oil that was purified by passage through 50 g of silica gel with 15% Et_2O in pentane as eluent. Removal of the solvent under reduced pressure gave a light-yellow oil that crystallized upon standing. Recrystallization from 50 mL of pentane yielded 8.99 g (69%) of the title compound as a white crystalline solid: mp 28.6 – 29.0 °C (pentane); ^1H NMR (400 MHz, CDCl_3) δ 1.26 (t, $J = 7.2$ Hz, 6H), 4.16–4.29 (m, 4H), 4.68 (s, 1H), 7.54 (d, $J = 8.2$ Hz, 2H), 7.62 (d, $J = 8.2$ Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 14.1, 57.9, 62.3, 124.2 (q, $J_{\text{C-F}} = 272$ Hz), 125.6 (q, $J_{\text{C-F}} = 3.7$ Hz), 130.0, 130.6 (q, $J_{\text{C-F}} = 32.6$ Hz), 136.9, 167.7; ^{19}F NMR (376 MHz, CDCl_3) δ –62.8. HRMS (DART-TOF) m/z calcd for $\text{C}_{14}\text{H}_{15}\text{F}_3\text{O}_4$ $[\text{M} + \text{H}]^+$ 305.1001, found 305.0990.

Diethyl 2-(3,5-bis(trifluoromethyl)phenyl)malonate.¹⁴ Following the representative procedure with minor modification, 6.00 g (20.0 mmol) of ethyl 2-(3,5-bis(trifluoromethyl)phenyl)acetate afforded a crude yellow oil that was purified by passage through 40 g of silica gel using 20% ethyl acetate in hexanes as eluent. Removal of the solvent afforded 6.30 g (85%) of the title compound as a light yellow oil: $n_D^{21} = 1.4250$; ^1H NMR (400 MHz, CDCl_3) δ 1.27 (t, $J = 7.1$ Hz, 6H), 4.16–4.32 (m, 4H), 4.74 (s, 1H), 7.86 (s, 1H), 7.91 (s, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 14.0, 57.6, 62.7, 122.5 (apparent septet, $J_{\text{C-F}} = 3.7$ Hz), 123.3 (q, $J_{\text{C-F}} = 272$ Hz), 130.0 (apparent q, $J_{\text{C-F}} = 3.6$ Hz), 132.0 (q, $J_{\text{C-F}} = 33.5$ Hz), 135.3, 167.0; ^{19}F NMR (376 MHz, CDCl_3) δ –62.9; HRMS (DART-TOF) m/z calcd for $\text{C}_{15}\text{H}_{14}\text{F}_6\text{O}_4$ $[\text{M} + \text{H}]^+$ 373.0875, found 373.0867.

Diethyl 2-(4-methoxyphenyl)malonate.¹⁴ Following the representative procedure, with the modification that the reaction mixture was heated at reflux for 7 h before work-up, 7.50 g (38.6 mmol) of ethyl 2-(4-methoxyphenyl)acetate afforded a light-yellow oil that was purified by column chromatography (100 g SiO_2 , 0 \rightarrow 10% Et_2O /hexanes; the product eluted in fractions after 6%

Et₂O/hexanes) to yield 6.20 g (60%) of the title compound as a colorless oil: $n_D^{20} = 1.4975$ (lit.¹⁵ $n_D^{20} = 1.4988$); ¹H NMR (400 MHz, CDCl₃) δ 1.26 (t, $J = 7.1$ Hz, 6H), 3.80 (s, 3H), 4.14–4.28 (m, 4H), 4.55 (s, 1H), 6.89 (d, $J = 8.7$ Hz, 2H), 7.32 (d, $J = 8.7$ Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 14.2, 55.5, 57.4, 61.9, 114.2, 125.2, 130.59, 159.7, 168.6.

Diethyl 2-(4-chlorophenyl)malonate. Following the procedure of Meyer and Levene for the synthesis of diethyl phenylmalonate,¹⁶ 20.99 g (106 mmol) of ethyl 2-(4-chlorophenyl)acetate afforded 8.65 g (30%) of the title compound as a colorless oil after distillation: bp 175 – 180 °C (10 mm) [lit.¹² bp 170 – 180 °C (27 mbar)]; $n_D^{21} = 1.4970$ (lit.¹⁷ $n_D^{25} = 1.4999$); ¹H NMR (400 MHz, CDCl₃) δ 1.25 (t, $J = 7.1$ Hz, 6H), 4.10–4.27 (m, 4H), 4.58 (s, 1H), 7.30 – 7.36 (m, 4H); ¹³C NMR (100 MHz, CDCl₃) δ 14.1, 57.4, 62.1, 128.9, 130.8, 131.4, 134.4, 167.9.

Synthesis of 2-Aryl-1,3-propanediols

2-(4-Trifluoromethylphenyl)-1,3-propanediol.¹³ A solution of 6.95 g (22.8 mmol) of diethyl (4-trifluoromethylphenyl)malonate in 50 mL of dry Et₂O was added to a 0 °C suspension of 1.30 g (34.2 mmol) of lithium aluminum hydride in 150 mL of Et₂O. The resulting mixture was stirred at room temperature overnight and then hydrolyzed by sequential, dropwise addition of 1.5 mL of water, 1.5 mL of a 1 M aqueous solution of sodium hydroxide, and 6 mL of water. The mixture was filtered through a pad of Celite and the solids were washed with three 150-mL portions of Et₂O. The combined filtrate and washings were dried (Na₂SO₄) and concentrated under reduced pressure to yield a thick oil which was purified by column chromatography (100 g SiO₂, 15 → 80% Et₂O/pentane, product eluted in fractions after 60% Et₂O/pentane). Combining relevant fractions and removal of the solvent yielded a solid which was recrystallized from pentane to afford 2.79 g (56%) of the title compound as a white crystalline solid: mp 48.8–50.0 °C (pentane); ¹H NMR (400 MHz, CDCl₃) δ 2.75 (br s, 2H), 3.05–3.18 (m, 1H), 3.87–4.04 (m, 4H), 7.34 (d, $J = 7.8$ Hz, 2H), 7.57 (d, $J = 7.8$ Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 49.6, 65.6, 124.3 (q, $J_{C-F} = 272$ Hz), 125.8 (apparent q, $J_{C-F} = 3.6$ Hz), 128.7, 129.7 (q, $J_{C-F} = 32.5$ Hz), 144.0; ¹⁹F

NMR (376 MHz, CDCl₃) δ -62.6; HRMS (DART-TOF) m/z calcd for C₁₀H₁₁F₃O₂ [M + H]⁺ 221.0789, found 221.0800.

2-(4-Bromophenyl)-1,3-propanediol.⁶ A solution of 15.80 g (50.1 mmol) of diethyl (4-bromophenyl)malonate in 75 mL of dry Et₂O was reduced with 2.85 g (75.2 mmol) of lithium aluminum hydride in 150 mL of Et₂O. The reaction mixture was worked up as described above, the solids were extracted overnight with Et₂O using a Soxhlet extractor, and the resulting oil was purified by column chromatography (100 g SiO₂, 20 → 100% Et₂O/pentane, product eluted in fractions after 60% Et₂O/pentane). The clear oil obtained after solvent removal crystallized upon standing and was recrystallized from pentane/ Et₂O to afford 5.50 g (48%) of the title compound as a white crystalline solid: mp 65.8–66.5 °C (pentane/ Et₂O); ¹H NMR (400 MHz, CDCl₃) δ 2.44 (br s, 2H), 3.02 (quintet, J = 6.4 Hz, 1H), 3.89 (dd, J = 10.7 Hz, J = 5.5 Hz, 2H), 4.02 (dd, J = 10.7 Hz, J = 7.6 Hz, 2H), 7.11 (d, J = 8.4 Hz, 2H), 7.45 (d, J = 8.4 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 49.3, 65.8, 121.2, 130.0, 132.1, 138.7; HRMS (DART-TOF) m/z calcd for C₉H₁₁BrO₂ [M + H]⁺ 231.0021, found 231.0042.

2-Phenyl-1,3-propanediol.¹⁸ A solution of 5.91 g (25.0 mmol) of diethyl phenylmalonate in 20 mL of dry Et₂O was reduced with 1.42 g (37.5 mmol) of lithium aluminum hydride in 100 mL of Et₂O. The reaction mixture was worked up as described above to afford an oil that crystallized upon standing. The solid was triturated with pentane to yield 3.18 g (84%) of the title compound: mp 51.8 – 52.3 °C (pentane) (lit.¹⁹ mp 50 – 51.5 °C); ¹H NMR (400 MHz, CDCl₃) δ 2.59 (br s, 2H), 3.02–3.12 (m, 1H), 3.86–4.03 (m, 4H), 7.22 (d, J = 7.3 Hz, 2H), 7.26 (t, J = 7.3 Hz, 1H), 7.33 (t, J = 7.3 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 49.9, 66.2, 127.4, 128.2, 129.0, 139.5.

2-(3,5-Bis(trifluoromethyl)phenyl)-1,3-propanediol. A solution of 5.00 g (13.4 mmol) of diethyl (3,5-bis(trifluoromethyl)phenyl)malonate in 50 mL of dry Et₂O was reduced with 765 mg (20.2 mmol) of lithium aluminum hydride in 150 mL of Et₂O. The reaction mixture was worked up as described above and the resulting yellow oil was purified by column chromatography (25 g SiO₂, 20% ethyl acetate/pentane then 70% ethyl acetate/pentane, product eluted in fractions after the addition of 70% ethyl

acetate/pentane) to yield a clear oil after solvent removal, which when triturated with CHCl_3 , crystallized upon standing to afford 762 mg (20%) of the title compound: mp 66.3 – 67.2 °C (CHCl_3); ^1H NMR (400 MHz, CDCl_3) δ 2.32 (br s, 2H), 3.17 (quintet, $J = 6.0$ Hz, 1H), 4.00 (dd, $J = 10.7$ Hz, $J = 5.5$ Hz, 2H), 4.02 (dd, $J = 10.7$ Hz, $J = 6.6$ Hz, 2H), 7.74 (s, 2H), 7.78 (s, 1H); ^{13}C NMR (100 MHz, CDCl_3) δ 49.2, 64.9, 121.3 (apparent septet, $J_{\text{C-F}} = 3.8$ Hz), 123.5 (q, $J_{\text{C-F}} = 272$ Hz), 128.6 (apparent q, $J_{\text{C-F}} = 3.4$ Hz), 132.0 (q, $J_{\text{C-F}} = 33.1$ Hz), 142.9; ^{19}F NMR (376 MHz, CDCl_3) δ -62.9; HRMS (DART-TOF) m/z calcd for $\text{C}_{11}\text{H}_{10}\text{F}_6\text{O}_2$ $[\text{M} + \text{H}]^+$ 289.0663, found 289.0662.

2-(4-Methoxyphenyl)-1,3-propanediol.⁶ A solution of 6.20 g (23.3 mmol) of diethyl (4-methoxyphenyl)malonate in 50 mL of dry Et_2O was reduced with 3.56 g (93.1 mmol) of lithium aluminum hydride in 150 mL of Et_2O . The reaction mixture was worked up as described above and the resulting solid was recrystallized from Et_2O /pentane to yield 2.88 g (68%) of the title compound as a white solid: mp 83.6–84.5 °C (Et_2O /pentane) (lit.²⁰ mp 83–85 °C); ^1H NMR (400 MHz, CDCl_3) δ 1.80 (br s, 2H), 3.06 (quintet, $J = 6.62$ Hz, 1H), 3.80 (s, 3H), 3.91 (dd, $J = 10.7$ Hz, $J = 5.7$ Hz, 2H), 3.97 (dd, $J = 10.7$ Hz, $J = 7.5$ Hz, 2H), 6.88 (d, $J = 8.7$ Hz, 2H), 7.16 (d, $J = 8.7$ Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 49.3, 55.5, 66.43, 114.4, 129.2, 131.3, 159.0.

2-(2-Pyridyl)-1,3-propanediol.²¹ Following a modification of the procedure of Lipp and Richard,²² 14.0 mL (101 mmol) of 2-picoline and 33.2 mL (404 mmol) of a 37 wt% solution of formaldehyde in water was heated at reflux for 48 h. After cooling to room temperature, 50 mL of methanol was added to the reaction flask and solvent was removed via rotary evaporation; the process was repeated three times. Then 50 mL of cyclohexane was added to the flask and volatile components were removed by rotary evaporation; this process was also repeated three times. The resulting dark brown, viscous oil was purified by column chromatography (100 g SiO_2 , 0 → 100% ethanol/ethyl acetate, product eluted after the addition of 40% ethanol/ethyl acetate) to yield 2.07 g (13%) of the title compound as a clear oil: ^1H NMR (400 MHz, CDCl_3) δ 3.04 (quintet, $J = 5.3$ Hz, 1H), 3.95 (dd, $J = 11.0$ Hz, $J = 5.0$ Hz, 2H), 4.04 (dd, $J = 11.0$ Hz, $J = 5.7$ Hz, 2H), 4.4 (br s, 2H), 7.14 (dd, $J = 7.3$ Hz, $J = 5.0$ Hz, 1H), 7.21

(d, $J = 7.8$ Hz, 1H), 7.62 (td, $J = 7.6$ Hz, $J = 1.7$ Hz, 1H) 8.42 (br d, $J = 4.2$ Hz, 1H); ^{13}C NMR (100 MHz, CDCl_3) δ 49.7, 63.6, 122.2, 123.8, 137.1, 148.7, 161.7; HRMS (DART-TOF) m/z calcd for $\text{C}_8\text{H}_{11}\text{NO}_2$ [$\text{M} + \text{H}$] $^+$ 154.0868, found 154.0838.

Synthesis of 5-Aryl-1,3-dioxanes

***cis*-2-Isopropyl-5-phenyl-1,3-dioxane (1) and *trans*-2-Isopropyl-5-phenyl-1,3-dioxane (2).** A mixture of 3.18 g (20.8 mmol) of 2-phenyl-1,3-propanediol, 3.00 g (41.6 mmol) of isobutyraldehyde, and 100 mg of *p*-TsOH in 35 mL of cyclohexane was stirred at 40 °C for 1.5 h and then was heated at reflux under a Dean-Stark trap for 4 h. The reaction mixture was allowed to cool to room temperature, 500 mg of anhydrous K_2CO_3 was added and mixture was transferred to a separatory funnel, washed with basic water (pH \sim 9, 3 x 50 mL), brine (1 x 50 mL), and dried (Na_2SO_4). The solvent was removed by rotary evaporation to yield 2.54 g of a light-yellow oil. A 370 mg portion of the product mixture was separated using an auto-flash column [40 g of pre-packed SiO_2 (40–60 μm , 60 Å)] with a gradient program 0 \rightarrow 4% Et_2O /hexanes over the course of 45 min: 5 mL fractions were collected; fractions 9–15 were enriched in the minor *cis*-isomer (**1**), pure *trans*-isomer (**2**) was collected in fractions 17–22. Concentration of fractions 17–22 afforded 140 mg (43%) of pure **2**. Fractions 9–15 were combined, concentrated, and the resulting oil taken-up in 350 μL of CH_2Cl_2 . Pure *cis*-isomer (**1**), 4.0 mg (*ca* 2%), was isolated from this solution by preparative GC on a 10 ft x 0.25 in 20% SE-30 on Anakrom (60–70 mesh) column using He as the carrier gas at a flow rate of 175 mL/min and an oven temperature of 170 °C: retention time of the *cis*-isomer (**1**) was 14.7 min and the *trans* isomer (**2**) was 16.3 min. This process was repeated as additional isomerically pure material was needed. The isomers **1** and **2** were distinguished using two-dimensional ^1H NOESY techniques.

***cis*-2-Isopropyl-5-phenyl-1,3-dioxane (1):** colorless oil; ^1H NMR (500 MHz, CDCl_3) δ 0.98 (d, $J = 6.8$ Hz, 6H), 1.85–1.92 (m, 1H), 2.58–2.64 (br m, 1H), 4.17 (dd, $J = 11.5$ Hz, $J = 3.1$ Hz, 2H), 4.21 (t, $J = 11.6$ Hz, 2H), 4.41 (d, $J = 4.6$ Hz, 1H), 7.24 (t, $J = 7.5$ Hz, 1H), 7.32 (t, $J = 7.5$ Hz, 2H), 7.56 (d, $J =$

7.8 Hz, 2H); ^{13}C NMR (125 MHz, CDCl_3) δ 17.1, 33.1, 39.7, 71.3, 106.2, 126.6, 128.5, 128.7, 143.6; HRMS (DART-TOF) m/z calcd for $\text{C}_{13}\text{H}_{18}\text{O}_2$ $[\text{M} + \text{H}]^+$ 207.1385, found 207.1398.

***trans*-2-Isopropyl-5-phenyl-1,3-dioxane (2):** colorless oil; ^1H NMR (400 MHz, CDCl_3) δ 1.00 (d, $J = 6.9$ Hz, 6H), 1.82–1.94 (m, 1H), 3.20 (tt, $J = 11.6$ Hz, $J = 4.5$ Hz, 1H), 3.81 (t, $J = 11.6$ Hz, 2H), 4.22 (dd, $J = 11.6$ Hz, $J = 4.5$ Hz), 4.34 (d, $J = 5.0$ Hz, 1H), 7.18 (d, $J = 7.1$ Hz, 2H), 7.26 (t, $J = 7.4$ Hz, 1H), 7.33 (t, $J = 7.3$ Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 17.3, 32.9, 41.6, 72.2, 106.0, 127.5, 127.9, 128.9, 138.2; HRMS (DART-TOF) m/z calcd for $\text{C}_{13}\text{H}_{18}\text{O}_2$ $[\text{M} + \text{H}]^+$ 207.1385, found 207.1390.

***cis*-2-*t*-Butyl-5-(4-chlorophenyl)-1,3-dioxane (3) and *trans*-2-*t*-Butyl-5-(4-chlorophenyl)-1,3-dioxane (4).** A solution of 5.00 g (29.3 mmol) of diethyl (4-chlorophenyl)malonate in 20 mL of dry Et_2O was reduced with 1.67 g (43.9 mmol) of lithium aluminum hydride in 100 mL of Et_2O . The reaction mixture was worked up as described above to give 2.32 g of 2-(4-chlorophenyl)-1,3-propanediol. The crude diol, 2.14 g (24.9 mmol) of pivaldehyde, and 237 mg of *p*-TsOH in 40 mL of cyclohexane was heated at reflux under a Dean-Stark trap for 12 h. The reaction mixture was allowed to cool to room temperature, 0.5 g of anhydrous K_2CO_3 was added, the mixture was stirred for 30 min, transferred to a separatory funnel with 50 mL of Et_2O , washed with basic water (pH \sim 9, 2 x 25 mL), brine (1 x 25 mL), and dried (Na_2SO_4). The solvent was removed by rotary evaporation to give 2.58 g of a light-yellow oil that was taken up in pentane, loaded onto 200 g of neutral alumina and purified via flash chromatography (0 \rightarrow 5% Et_2O /pentane); 25 mL fractions were collected. Fractions 14–31, containing the isomers of interest, were concentrated to afford 1.34 g of a white solid. GC analysis revealed that material consisted of the *trans*-**(4)** and *cis*-**(3)** dioxanes in an approx. 4:1 ratio. Separation of the isomers was achieved by preparative TLC of a 50 mg portion of the mixture on a 1000 μm SiO_2 glass-backed plate using a 5% solution of ethyl acetate in hexanes as an eluent to give 8.0 mg (16%) of **3** ($R_f = 0.44$) and 40 mg (80%) of **4** ($R_f = 0.53$). This process was repeated as additional isomerically pure material was needed. Isomers **3** and **4** were distinguished using two-dimensional ^1H NOESY techniques. Each of the isomers was recrystallized, as described below, to give analytical samples used in the equilibration and crystallographic studies.

***cis*-2-*t*-Butyl-5-(4-chlorophenyl)-1,3-dioxane (3):** colorless solid; mp 65.7–66.6 °C (pentane); ¹H NMR (400 MHz, CDCl₃) δ 0.95 (s, 9H), 2.54–2.58 (br m, 1H), 4.10–4.20 (m, 4H), 4.23 (s, 1H), 7.28 (d, *J* = 8.4 Hz, 2H), 7.50 (d, *J* = 8.4 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 24.9, 35.4, 39.2, 71.3, 108.4, 128.5, 130.2, 132.4, 142.2; HRMS (DART-TOF) *m/z* calcd for C₁₄H₁₉ClO₂ [M – H]⁺ 253.0995, found 253.1016.

***trans*-2-*t*-Butyl-5-(4-chlorophenyl)-1,3-dioxane (4):** white solid; mp 72.8–73.9 °C (pentane); ¹H NMR (400 MHz, CDCl₃) δ 0.96 (s, 9H), 3.15 (tt, *J* = 11.3 Hz, *J* = 4.6 Hz, 1H), 3.74 (t, *J* = 11.5 Hz, 2H), 4.17 (s, 1H), 4.18 (dd, *J* = 11.6 Hz, *J* = 4.6 Hz), 7.11 (d, *J* = 8.4 Hz, 2H), 7.29 (d, *J* = 8.5 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 25.0, 35.0, 41.0, 72.1, 108.0, 129.1, 129.2, 133.3, 136.7; HRMS (DART-TOF) *m/z* calcd for C₁₄H₁₉ClO₂ [M – H]⁺ 253.0995, found 253.0981.

***cis*-5-(4-Bromophenyl)-2-*t*-butyl-1,3-dioxane (5) and *trans*-5-(4-Bromophenyl)-2-*t*-butyl-1,3-dioxane (6).** A mixture of 5.02 g (21.8 mmol) of 2-(4-bromophenyl)-1,3-propanediol, 4.70 g (54.6 mmol) of pivaldehyde, and 123 mg of *p*-TsOH in 30 mL of benzene was stirred at room temperature for 30 min and then gradually heated over a period of 5 h and held at reflux under a Dean-Stark trap for 12 h. The reaction mixture was allowed to cool to room temperature, 500 mg of anhydrous K₂CO₃ was added, the mixture was stirred for 30 min, transferred to a separatory funnel with 100 mL of Et₂O, washed with basic water (pH ~ 9, 2 x 50 mL), brine (1 x 50 mL), and dried (Na₂SO₄). The solvent was removed by rotary evaporation, the residue was taken up in a solution of 40% Et₂O/pentane and passed through a short bed of SiO₂. Solvent was removed by rotary evaporation to give 6.27 g (96%) of a mixture of **5** and **6**. Separation of compounds **5** and **6** was achieved by preparative TLC of a 52 mg portion of the mixture on a 1000 μm SiO₂ glass-backed plate using a 6% solution of Et₂O in pentane as an eluent to give 9.3 mg (18%) of **5** (*R_f* = 0.51) and 28 mg of **6** (*R_f* = 0.68). This process was repeated as additional isomerically pure material was needed. Isomers **5** and **6** were distinguished using two-dimensional ¹H NOESY techniques. Each of the isomers was recrystallized, as described below, to give analytical samples used in the equilibration studies.

***cis*-5-(4-Bromophenyl)-2-*t*-butyl-1,3-dioxane (5):** colorless solid; mp 60.6–61.5 °C (pentane); ¹H NMR (400 MHz, CDCl₃) δ 0.95 (s, 9H), 2.52–2.56 (br m, 1H), 4.12–4.16 (m, 4H), 4.23 (s, 1H), 7.42–7.46 (m, 4H); ¹³C NMR (100 MHz, CDCl₃) δ 24.9, 35.4, 39.2, 71.3, 108.4, 120.5, 130.6, 131.4, 142.7; HRMS (DART-TOF) *m/z* calcd for C₁₄H₁₉BrO₂ [M + H]⁺ 299.0647, found 299.0652.

***trans*-5-(4-Bromophenyl)-2-*t*-butyl-1,3-dioxane (6):** white solid; mp 71.5–72.3 °C (pentane); ¹H NMR (400 MHz, CDCl₃) δ 0.95 (s, 9H), 3.13 (tt, *J* = 11.3 Hz, *J* = 4.6 Hz, 1H), 3.73 (t, *J* = 11.5 Hz, 2H), 4.17 (s, 1H), 4.18 (dd, *J* = 11.6 Hz, *J* = 4.5 Hz), 7.05 (d, *J* = 8.3 Hz, 2H), 7.44 (d, *J* = 8.4 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 25.0, 35.0, 41.1, 72.0, 108.0, 121.3, 129.5, 132.1, 137.2; HRMS (DART-TOF) *m/z* calcd for C₁₄H₁₉BrO₂ [M + H]⁺ 299.0647, found 299.0617.

***cis*-2-*t*-Butyl-5-(4-trifluoromethylphenyl)-1,3-dioxane (7) and *trans*-2-*t*-Butyl-5-(4-trifluoromethylphenyl)-1,3-dioxane (8).** A mixture of 1.72 g (10.0 mmol) of 2-(4-trifluoromethylphenyl)-1,3-propanediol, 4.70 g (54.6 mmol) of pivaldehyde, and 75 mg of *p*-TsOH in 20 mL of benzene was stirred at room temperature for 30 min and then gradually heated over a period of 5 h and held at reflux under a Dean-Stark trap for 12 h. The reaction mixture was allowed to cool to room temperature, 0.5 g of anhydrous K₂CO₃ was added, the mixture was stirred for 30 min, transferred to a separatory funnel with 50 mL of Et₂O, washed with basic water (pH ~ 8, 3 x 50 mL), brine (1 x 50 mL), and dried (Na₂SO₄). The solvent was removed by rotary evaporation to yield a clear oil that crystallized upon standing. Separation of compounds **7** and **8** was achieved by preparative TLC of a 72 mg portion of the mixture on a 1000 μm SiO₂ glass-backed plate using an 8% solution of Et₂O in pentane as eluent to give 12 mg (17%) of **7** (*R_f* = 0.50) and 51 mg (71%) of **8** (*R_f* = 0.71). This process was repeated as additional isomerically pure material was needed. Isomers **7** and **8** were distinguished using two-dimensional ¹H NOESY techniques. Each of the isomers was recrystallized, as described below, to give analytical samples used in the equilibration studies.

***cis*-2-*t*-Butyl-5-(4-trifluoromethylphenyl)-1,3-dioxane (7):** colorless solid; mp 37.1–38.0 °C (pentane); ¹H NMR (400 MHz, CDCl₃) δ 0.96 (s, 9H), 2.62–2.68 (br m, 1H), 4.14–4.24 (m, 4H), 4.25 (s, 1H), 7.57

(d, $J = 8.1$ Hz, 2H), 7.69 (d, $J = 8.1$ Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 24.9, 35.4, 39.6, 71.1, 108.5, 124.5 (q, $J_{\text{C-F}} = 272$ Hz), 125.3 (q, $J_{\text{C-F}} = 3.8$ Hz), 128.9 (q, $J_{\text{C-F}} = 32.5$ Hz), 129.1, 147.7; ^{19}F NMR (376 MHz, CDCl_3) δ -62.5; HRMS (DART-TOF) m/z calcd for $\text{C}_{15}\text{H}_{19}\text{F}_3\text{O}_2$ $[\text{M} - \text{H}]^+$ 287.1259, found 287.1286.

***trans*-2-*t*-Butyl-5-(4-trifluoromethylphenyl)-1,3-dioxane (8):** white solid; mp 87.1–87.9 °C (CH_2Cl_2); ^1H NMR (400 MHz, CDCl_3) δ 0.96 (s, 9H), 3.24 (tt, $J = 11.3$ Hz, $J = 4.6$ Hz, 1H), 3.79 (t, $J = 11.5$ Hz, 2H), 4.19 (s, 1H), 4.21 (dd, $J = 11.6$ Hz, $J = 4.6$ Hz, 2H), 7.29 (d, $J = 8.1$ Hz, 2H), 7.58 (d, $J = 8.1$ Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 25.0, 35.1, 41.5, 71.9, 108.1, 124.3 (q, $J_{\text{C-F}} = 272$ Hz), 125.9 (q, $J_{\text{C-F}} = 3.7$ Hz), 128.3, 129.8 (q, $J_{\text{C-F}} = 32.6$ Hz), 129.1, 142.4; ^{19}F NMR (376 MHz, CDCl_3) δ -62.7; HRMS (DART-TOF) m/z calcd for $\text{C}_{15}\text{H}_{19}\text{F}_3\text{O}_2$ $[\text{M} - \text{H}]^+$ 287.1259, found 287.1286.

***cis*-2-*t*-Butyl-5-(3,5-bis(trifluoromethyl)phenyl)-1,3-dioxane (9) and *trans*-2-*t*-Butyl-5-(3,5-bis(trifluoromethyl)phenyl)-1,3-dioxane (10).** A mixture of 709 mg (2.46 mmol) of 2-(3,5-bis(trifluoromethyl)phenyl)-1,3-propanediol, 423 mg (4.92 mmol) of pivaldehyde, and 53 mg of *p*-TsOH in 20 mL of benzene was stirred at room temperature for 30 min and then gradually heated over a period of 5 h and held at reflux under a Dean-Stark trap for 12 h. The reaction mixture was allowed to cool to room temperature, 500 mg of anhydrous K_2CO_3 was added, the mixture was stirred for 30 min, transferred to a separatory funnel with 50 mL of Et_2O , washed with basic water (pH ~ 8, 3 x 25 mL), brine (1 x 25 mL), and dried (Na_2SO_4). The solvent was removed by rotary evaporation to yield 837 mg (96%) of the title compounds as a mixture of isomers. Separation of isomers **9** and **10** was achieved by column chromatography (150 g SiO_2 , 0 \rightarrow 10% Et_2O /pentane); 25 mL fractions were collected: once material started to elute (*ca* 4% Et_2O /pentane), 25 mg (3%) of pure *trans*-isomer (**10**) was collected in fractions 1 and 2; 106 mg (13%) of pure *cis*-isomer (**9**) was collected in fractions 12–14. Additionally, fractions 3–11, which contained a mixture of **9** and **10**, were combined and further separation was effected by preparative TLC of a 71 mg portion of the mixture on a 1000 μm SiO_2 glass-backed plate using a 10% solution of Et_2O in pentane as eluent. From this sample, an additional 21 mg (30%) of **9** (R_f

= 0.67) and 39 mg (55%) of **10** (R_f = 0.87) was isolated. This process was repeated as additional isomerically pure material was needed. Isomers **9** and **10** were distinguished using two-dimensional ^1H NOESY techniques. Each of the isomers was recrystallized, as described below, to give analytical samples used in the equilibration studies.

cis-2-*t*-Butyl-5-(3,5-bis(trifluoromethyl)phenyl)-1,3-dioxane (9): white solid; mp 44.2–45.1 °C (CH_2Cl_2); ^1H NMR (400 MHz, CDCl_3) δ 0.97 (s, 9H), 2.71–2.75 (m, 1H), 4.14–4.24 (m, 4H), 4.28 (s, 1H), 7.77 (s, 1H), 8.10 (s, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 24.8, 35.4, 39.6, 70.8, 108.6, 120.7 (septet, $J_{\text{C-F}}$ = 3.8 Hz), 123.7 (q, $J_{\text{C-F}}$ = 273 Hz), 129.3 (apparent quartet, $J_{\text{C-F}}$ = 2.6 Hz), 131.5 (q, $J_{\text{C-F}}$ = 33.0 Hz), 146.0; ^{19}F NMR (376 MHz, CDCl_3) δ –62.8; HRMS (DART-TOF) m/z calcd for $\text{C}_{16}\text{H}_{18}\text{F}_6\text{O}_2$ $[\text{M} - \text{H}]^+$ 355.1133, found 355.1146.

trans-2-*t*-Butyl-5-(3,5-bis(trifluoromethyl)phenyl)-1,3-dioxane (10): white solid; mp 98.6–99.5 °C (CH_2Cl_2); ^1H NMR (400 MHz, CDCl_3) δ 0.96 (s, 9H), 3.32 (tt, J = 11.3 Hz, J = 4.6 Hz, 1H), 3.81 (t, J = 11.4 Hz, 2H), 4.22 (s, 1H), 4.24 (dd, J = 11.6 Hz, J = 4.6 Hz, 2H), 7.62 (s, 2H), 7.78 (s, 1H); ^{13}C NMR (100 MHz, CDCl_3) δ 24.9, 35.1, 41.4, 71.6, 108.1, 121.6 (septet, $J_{\text{C-F}}$ = 3.8 Hz), 123.4 (q, $J_{\text{C-F}}$ = 273 Hz), 128.1 (apparent quartet, $J_{\text{C-F}}$ = 2.7 Hz), 132.4 (q, $J_{\text{C-F}}$ = 33.3 Hz), 140.9; ^{19}F NMR (376 MHz, CDCl_3) δ –63.0; HRMS (DART-TOF) m/z calcd for $\text{C}_{16}\text{H}_{18}\text{F}_6\text{O}_2$ $[\text{M} - \text{H}]^+$ 355.1133, found 355.1145.

cis-2-*t*-Butyl-5-(4-methoxyphenyl)-1,3-dioxane (11) and trans-2-*t*-Butyl-5-(4-methoxyphenyl)-1,3-dioxane (12). A mixture of 5.68 g (31.2 mmol) of 2-(4-methoxyphenyl)-1,3-propanediol, 5.37 g (62.4 mmol) of pivaldehyde, and 125 mg of *p*-TsOH in 40 mL of benzene was stirred at room temperature for 30 min and then gradually heated over a period of 5 h and held at reflux under a Dean-Stark trap for 4 h. The reaction mixture was allowed to cool to room temperature, 500 mg of anhydrous K_2CO_3 was added, the mixture was stirred for 30 min, transferred to a separatory funnel with 100 mL of Et_2O , washed with basic water (pH ~ 8, 3 x 50 mL), brine (1 x 50 mL), and dried (Na_2SO_4). The solvent was removed by rotary evaporation to yield 4.33 g (56%) of the title compounds as a mixture of isomers. A 103 mg portion of this mixture was dissolved in 300 μL of Et_2O . Pure *cis*-isomer (**11**), 2.2 mg (2%), and pure

trans-isomer (**12**), 26.6 mg (26%), were isolated from this solution by preparative GC on a 10 ft x 0.25 in 20% SE-30 on Anakrom (60–70 mesh) column using He as the carrier gas at a flow rate of 175 mL/min and an oven temperature of 200 °C: retention time of the *cis*-isomer (**11**) was 27.5 min and the *trans*-isomer (**12**) was 33.2 min. This process was repeated as additional isomerically pure material was needed. Isomers **11** and **12** were distinguished using two-dimensional ¹H NOESY techniques. The solid *trans*-isomer (**12**) was recrystallized from CH₂Cl₂; analytically pure samples were used in the equilibration studies.

***cis*-2-*t*-Butyl-5-(4-methoxyphenyl)-1,3-dioxane (**11**):** colorless oil; ¹H NMR (400 MHz, CDCl₃) δ 0.96 (s, 9H), 2.51–2.56 (br m, 1H), 3.80 (s, 3H), 4.10–4.20 (m, 4H), 4.23 (s, 1H), 6.86 (d, *J* = 8.8 Hz, 2H), 7.48 (d, *J* = 8.8 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 25.0, 35.4, 39.0, 55.5, 71.7, 108.4, 113.8, 129.7, 136.1, 158.4; HRMS (DART-TOF) *m/z* calcd for C₁₅H₂₂O₃ [*M* – H]⁺ 249.1491, found 249.1476.

***trans*-2-*t*-Butyl-5-(4-methoxyphenyl)-1,3-dioxane (**12**):** white solid; mp 58.3–59.1 °C (CH₂Cl₂); ¹H NMR (400 MHz, CDCl₃) δ 0.95 (s, 9H), 3.11 (tt, *J* = 11.4 Hz, *J* = 4.7 Hz, 1H), 3.74 (t, *J* = 11.5 Hz, 2H), 3.79 (s, 3H), 4.17 (s, 1H), 4.18 (dd, *J* = 11.7 Hz, *J* = 4.7 Hz, 2H), 6.86 (d, *J* = 8.7 Hz, 2H), 7.10 (d, *J* = 8.7 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 25.1, 35.0, 40.7, 55.5, 72.5, 108.0, 114.4, 128.8, 130.3, 159.0; HRMS (DART-TOF) *m/z* calcd for C₁₅H₂₂O₃ [*M* – H]⁺ 249.1491, found 249.1473.

***cis*-2-*t*-Butyl-5-(4-trimethylsilylphenyl)-1,3-dioxane (**13**) and *trans*-2-*t*-Butyl-5-(4-trimethylsilylphenyl)-1,3-dioxane (**14**).** Under an atmosphere of dry argon, a solution of 1.50 g (5.00 mmol) of an isomeric mixture of **5** and **6** in 25 mL of anhydrous Et₂O was cooled to –78 °C and 6.00 mL (12.0 mmol) of a 2.00 M solution of *t*-BuLi in heptane was added over a period of 5 min. The mixture was stirred for an additional 10 min at –78 °C, allowed to warm to room temperature and stirred for 30 min. A separate flask was charged with a solution of 597 mg (5.50 mmol) of trimethylsilyl chloride in 25 mL of anhydrous Et₂O. The orange reaction mixture was then transferred dropwise by cannula into the flask containing the TMSCl solution. The reaction mixture was stirred for 30 min at room temperature, 20 mL of saturated, aqueous NaHCO₃ was added, and the contents were transferred to a separatory funnel.

The organic layer was separated, the aqueous layer extracted with Et₂O (2 x 25 mL) and the combined organic layers were washed with water (2 x 25 mL), brine (1 x 25 mL), and dried (K₂CO₃). Benzene (25 mL) was added and solvent was removed under reduced pressure; this process was repeated twice to azeotropically remove heptane. Upon standing, the resulting clear oil crystallized to yield 1.42 g (97%) of a white crystalline solid. Preparative TLC of a 50 mg portion of this mixture on a 1000 µm SiO₂ glass-backed plate using a 6% solution of Et₂O in pentane as eluent afforded 26 mg (52%) of pure **14** (*R_f* = 0.80). Pure *cis*-isomer (**13**), 5.0 mg (*ca* 2.5%), was isolated from a 205 mg portion of the product mixture by preparative GC on a 10 ft x 0.25 in 20% SE-30 on Anakrom (60–70 mesh) column using He as the carrier gas at a flow rate of 175 mL/min and an oven temperature of 200 °C: retention time of the *cis*-isomer (**13**) was 31.8 min and the *trans*-isomer (**14**) was 38.3 min. This process was repeated as additional isomerically pure material was needed. Isomers **13** and **14** were distinguished using two-dimensional ¹H NOESY techniques. The solid *trans*-isomer (**14**) was recrystallized from pentane; analytically pure samples were used in the equilibration studies.

***cis*-2-*t*-Butyl-5-(4-trimethylsilylphenyl)-1,3-dioxane (**13**):** colorless oil; ¹H NMR (400 MHz, CDCl₃) δ 0.26 (s, 9H), 0.96 (s, 9H), 2.55–2.59 (br m, 1H), 4.13–4.23 (m, 4H), 4.24 (s, 1H), 7.48 (d, *J* = 8.0 Hz, 2H), 7.55 (d, *J* = 8.0 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ –0.9, 25.0, 35.4, 39.8, 71.4, 108.4, 128.2, 133.5, 138.1, 144.4; HRMS (DART-TOF) *m/z* calcd for C₁₇H₂₈O₂Si [*M* + *H*]⁺ 293.1937, found 293.1934, *m/z* calcd for C₁₇H₂₈O₂Si [*M* - *H*]⁺ 291.1780, found 291.1767.

***trans*-2-*tert*-Butyl-5-(4-trimethylsilylphenyl)-1,3-dioxane (**14**):** white solid; mp 87.9–88.6 °C (pentane); ¹H NMR (400 MHz, CDCl₃) δ 0.28 (s, 9H), 0.98 (s, 9H), 3.18 (tt, *J* = 11.4 Hz, *J* = 4.6 Hz, 1H), 3.81 (t, *J* = 11.4 Hz, 2H), 4.21 (s, 1H), 4.23 (dd, *J* = 11.6 Hz, *J* = 4.5 Hz, 2H), 7.19 (d, *J* = 7.8 Hz, 2H), 7.50 (d, *J* = 7.8 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ –0.9, 25.1, 35.0, 41.6, 72.3, 108.0, 127.4, 134.0, 138.8, 139.6; HRMS (DART-TOF) *m/z* calcd for C₁₇H₂₈O₂Si [*M* + *H*]⁺ 293.1937, found 293.1905, *m/z* calcd for C₁₇H₂₈O₂Si [*M* - *H*]⁺ 291.1780, found 291.1778

***cis*-2-*t*-Butyl-5-(2-pyridyl)-1,3-dioxane (15) and *trans*-2-*t*-Butyl-5-(2-pyridyl)-1,3-dioxane (16).** A mixture of 1.78 g (11.6 mmol) of 2-(2-pyridyl)-1,3-propanediol, 2.00 g (23.3 mmol) of pivaldehyde, and 2.43 g (12.8 mmol) of *p*-TsOH in 40 mL of cyclohexane was stirred at room temperature for 1.5 h and then held at reflux under a Dean-Stark trap for 12 h. The reaction mixture was allowed to cool to room temperature, 1.5 g of anhydrous K₂CO₃ was added, the mixture was stirred for 1.5 h, transferred to a separatory funnel with 100 mL of Et₂O, rinsed with a solution of saturated, aqueous Na₂CO₃ (2 x 25 mL) washed with basic water (pH ~ 8, 3 x 50 mL), brine (1 x 50 mL), and dried (Na₂SO₄). The solvent was removed by rotary evaporation to give 2.95 g of a light yellow oil that was dissolved in pentane and loaded onto 250 g of neutral alumina. The column was eluted using a gradient (0 → 10% Et₂O/pentane); 30 mL fractions were collected: 123 mg (5%) of pure *trans*-isomer (**16**) was collected in fractions 19-22; 369 mg (14%) of pure *cis*-isomer (**15**) was collected in fractions 26-28. Isomers **15** and **16** were distinguished using two-dimensional ¹H NOESY techniques. Each of the isomers was recrystallized, as described below, to give analytically pure samples.

***cis*-2-*t*-Butyl-5-(2-pyridyl)-1,3-dioxane (15):** white solid, mp 44.8–45.4 °C (pentane); ¹H NMR (400 MHz, CDCl₃) δ 0.92 (s, 9H), 2.78–2.82 (br m, 1H), 4.17 (br d, *J* = 11.5 Hz, 2H), 4.25 (s, 1H), 4.38 (d, *J* = 11.5 Hz, 2H), 7.14 (t, *J* = 5.5 Hz, 1H), 7.65 (tt, *J* = 7.7 Hz, *J* = 2.0 Hz, 1H), 7.85 (d, *J* = 8.0 Hz, 1H), 8.52 (br d, *J* = 4.4 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 24.9, 35.3, 42.2, 70.2, 108.3, 121.7, 123.2, 136.4, 149.1, 162.5; HRMS (DART-TOF) *m/z* calcd for C₁₃H₁₉NO₂ [*M* + *H*]⁺ 222.1489, found 222.1480.

***trans*-2-*t*-Butyl-5-(2-pyridyl)-1,3-dioxane (16):** white solid, mp 71.5–72.3 °C (pentane); ¹H NMR (400 MHz, CDCl₃) δ 0.94 (s, 9H), 3.30 (tt, *J* = 11.1 Hz, *J* = 4.6 Hz, 1H), 3.99 (t, *J* = 11.4 Hz, 2H), 4.20 (s, 1H), 4.26 (dd, *J* = 11.5 Hz, *J* = 4.6 Hz, 2H), 7.12 (apparent t, *J* = 6.5 Hz, 2H) 7.13 (dd, *J* = 7.6 Hz, *J* = 5.2 Hz, 2H), 7.59 (td, *J* = 7.6 Hz, *J* = 1.7 Hz, 1H), 8.52 (br d, *J* = 4.6 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 25.0, 35.0, 43.1, 71.3, 107.9, 122.2, 123.32, 136.7, 149.7, 158.5; HRMS (DART-TOF) *m/z* calcd for C₁₃H₁₉NO₂ [*M* + *H*]⁺ 222.1489, found 222.1513.

***cis*-2-*t*-Butyl-5-(2-pyridyl)-1,3-dioxane hydrobromide (17).** A solution of 125 mg (0.56 mmol) of **15** and 387 mg (2.82 mmol) of freshly distilled *t*-butyl bromide in 2.5 mL of dry CHCl₃ was heated at reflux for 12 h and then allowed to cool to room temperature.²³ Volatile components were removed by rotary evaporation to yield 165 mg (98%) of the title compound as an off-white powder. The solid was recrystallized from CH₂Cl₂/pentane to give colorless crystals: mp (dec) 178–181 °C; ¹H NMR (400 MHz, CDCl₃) δ 0.91 (s, 9H), 3.87–3.91 (br m, 1H), 4.22–4.40 (m, 4H), 4.27 (s, 1H), 7.87 (t, *J* = 6.5 Hz, 1H), 8.37 (td, *J* = 7.9 Hz, *J* = 1.2 Hz, 1H), 8.49 (d, *J* = 8.2 Hz, 1H), 8.70 (d, *J* = 5.6 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 24.7, 35.3, 36.7, 69.3, 108.7, 125.0, 128.1, 140.3, 145.4, 158.4; HRMS (DART-TOF) *m/z* calcd for C₁₃H₂₀BrNO₂ [M – Br]⁺ 222.1489, found 222.1520.

***trans*-2-*t*-Butyl-5-(2-pyridyl)-1,3-dioxane hydrobromide (18).** A solution of 54.3 mg (0.25 mmol) of **16** and 171.3 mg (1.25 mmol) of freshly distilled *t*-butyl bromide in 5 mL of dry chloroform was heated at reflux for 12 h and then allowed to cool to room temperature.²³ Volatile components were removed by rotary evaporation to yield 70.4 mg (93%) of an off-white powder that was recrystallized from CHCl₃/Et₂O: mp (dec) 156–170 °C; ¹H NMR (400 MHz, CDCl₃) δ 0.92 (s, 9H), 1.78 (br s, 1H exchanges), 3.84 (tt, *J* = 6.0 Hz, *J* = 4.8 Hz, 1H), 4.24–4.40 (m, 4H), 4.41 (s, 1H), 7.78 (d, *J* = 8.0, 1H), 7.92 (t, *J* = 6.4 Hz, 1H), 8.41 (td, *J* = 7.9, *J* = 1.4, 1H), 8.91 (d, *J* = 5.0 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 24.8, 35.1, 41.1, 69.3, 107.7, 125.7, 127.0, 142.5, 146.4, 153.4; HRMS (DART-TOF) *m/z* calcd for C₁₃H₂₀BrNO₂ [M – Br]⁺ 222.1489, found 222.1472. Rapid equilibration of **18** to **17** occurs on standing and especially in solution. For this reason, the spectroscopic data reported above for **18** was obtained from mixtures of **18** and **17**. Detailed NMR spectra are provided.

Equilibrations

For each pair of anancomeric dioxanes equilibrium was approached independently from pure samples of each isomer. The isomers were equilibrated at room temperature (~23 °C) in sealed ampoules under nitrogen as solutions in cyclohexane and Et₂O over Amberlyst-15 resin (20-30 beads). Periodically samples were opened and neutralized by shaking with anhydrous K₂CO₃. The area ratio of the isomers

was then determined by GC analysis using one of the following columns: a 30 m x 0.25 mm x 0.25 μ m Optima-225 50% cyanopropyl/50% phenylmethyl polysiloxane column or a 30 m x 0.25 mm x 0.25 μ m EC-1 100% dimethyl polysiloxane. The analysis parameters are detailed below. When the same area ratios were obtained from initially pure samples of each isomer, it was deemed that equilibrium had been attained. Area ratios for each equilibrium were taken as the average of 5 – 14 independent determinations from each side, the isomers were assumed to have identical GC response ratios, and the equilibrium constant for the each equilibrium (Table 1-9) was determined from these area ratios.

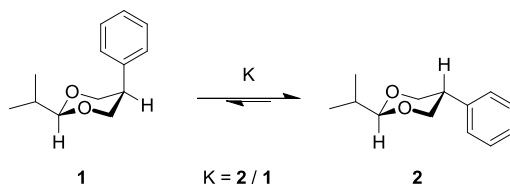
X-ray Crystallography

Structures were solved by direct methods using SHELXS and refined against F^2 on all data by full-matrix least squares with SHELXL.²⁴ All non-hydrogen atoms were refined anisotropically. Hydrogen atoms were included in the model at geometrically calculated positions and refined using a riding model. The isotropic displacement parameters of all hydrogen atoms were fixed to 1.2 times the U value of the atoms to which they are linked (1.5 times for methyl groups). The full numbering scheme of compounds **3** and **15** can be found below. Full details of the X-ray structure determination are located in the CIF. Additionally, CCDC numbers 1498697 (**3**) and 1498696 (**15**) contain the supplementary crystallographic data for this paper.²⁵

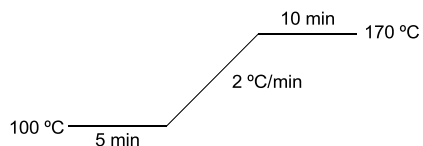
Calculations

The calculations and the Hirshfeld charge calculations were carried out using Gaussian-09.²⁶ The structures were drawn using CYLview 1.0b.²⁷

Gas Chromatography Parameters, Representative Chromatograms, and Equilibration Data



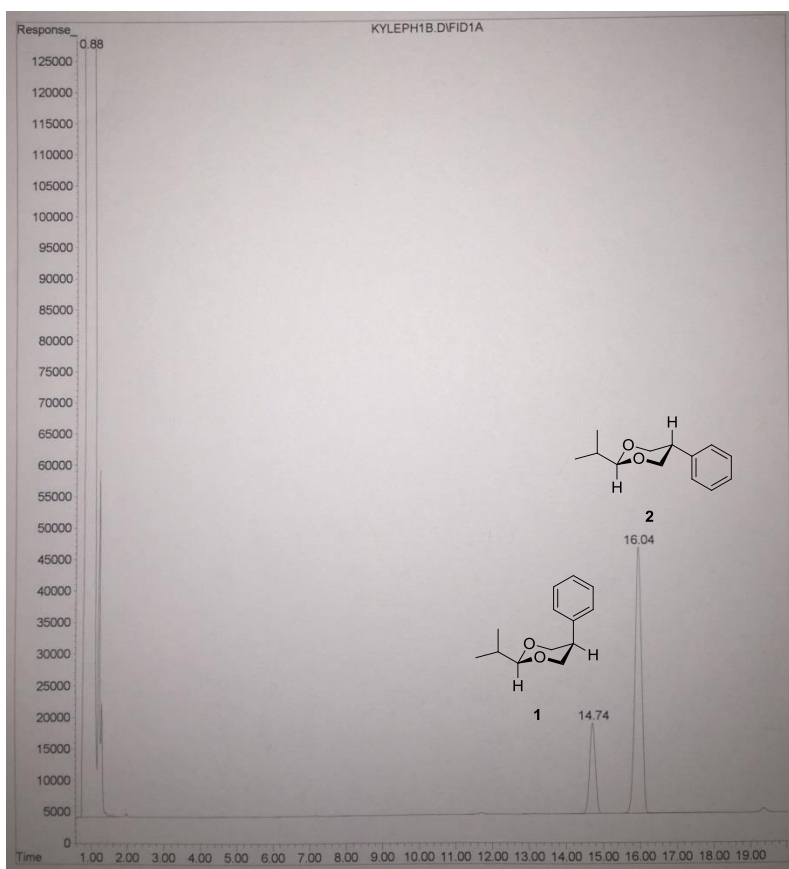
GC column: EC-1; 100% dimethyl polysiloxane; 30 meters; id- 0.25 mm; film- 0.25 μm

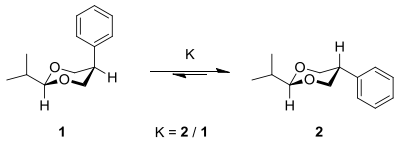


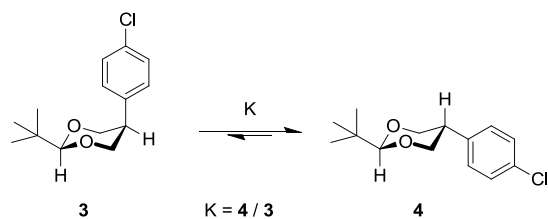
Program Description

The initial temperature was set at 100 °C for five minutes and increased at a rate of 2 °C/min and held at a final temperature of 170 °C for a period of 10 minutes.

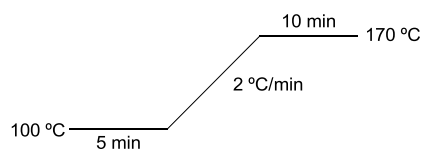
Compound	Ret. Time
1	14.74 min
2	16.04 min



<div style="text-align: center;">  <p>1 $K = 2 / 1$ 2</p> </div>									
Equilibrium study from 5-phenyl- <i>cis</i> -2-isopropyl-1,3-dioxane 1 in ether									
Area of axial phenyl isomer (1)	Area of equatorial phenyl isomer (2)	K	K _{Av}	Overall \bar{K}	$(K - \bar{K})^2$	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
6947508	41103428	5.91628	6.1061	6.0935467	0.03142	1.2625574	0.072530379	-1.06360771	-1.064 +/- 0.007 kcal/mol
6728136	44966213	6.68331			0.34782			-1.070571503	-0.006963793
10651626	69983953	6.57026			0.22726			-1.05656053	-0.00704718
995142	5905196	5.93402			0.02545				
1122012	6716538	5.98616			0.01153				
1638846	10203297	6.2259			0.01752				
740591	3981750	5.37645			0.51423				
1486421	9150756	6.15623			0.00393				
Equilibrium study from 5-phenyl- <i>trans</i> -2-isopropyl-1,3-dioxane 2 in ether									
Area of axial phenyl isomer (1)	Area of equatorial phenyl isomer (2)	K	K _{Av}		$(K - \bar{K})^2$				
3009664	18533945	6.15814	6.081		0.00417				
3211751	19729273	6.14284			0.00243				
4888498	29726601	6.08093			0.00016				
3025204	18747992	6.19727			0.01076				
3315636	19435604	5.8618			0.05371				
4110225	24658357	5.99927			0.00889				
2534385	15569090	6.14314			0.00246				
2741386	16625775	6.06473			0.00083				
Equilibrium study from 5-phenyl- <i>cis</i> -2-isopropyl-1,3-dioxane 1 in cyclohexane									
Area of axial phenyl isomer (1)	Area of equatorial phenyl isomer (2)	K	K _{Av}	Overall \bar{K}	$(K - \bar{K})^2$	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
2166372	13244282	6.11358	5.7038	5.712324	0.161	0.9807656	0.048323453	-1.025586167	-1.025 +/- 0.005 kcal/mol
1347185	7899926	5.86402			0.02301			-1.030543894	0.004957727
1995158	10964129	5.49537			0.04707			-1.020586321	-0.004999845
2380990	13727083	5.76528			0.0028				
1086893	6226817	5.72901			0.00028				
1323724	7762767	5.86434			0.02311				
1138280	6574342	5.77568			0.00401				
1200889	6983296	5.81511			0.01056				
867289	4891902	5.64045			0.00517				
817935	4443644	5.43276			0.07816				
1111963	6391700	5.74812			0.00128				
713328	3863536	5.41621			0.08768				
831344	4563724	5.48957			0.04962				
Equilibrium study from 5-phenyl- <i>trans</i> -2-isopropyl-1,3-dioxane 2 in cyclohexane									
Area of axial phenyl isomer (1)	Area of equatorial phenyl isomer (2)	K	K _{Av}		$(K - \bar{K})^2$				
1181321	6879287	5.82339	5.7337		0.01233				
1040969	5928416	5.69509			0.0003				
2489811	14407793	5.7867			0.00553				
1288751	7495569	5.81615			0.01078				
1339861	7900095	5.8962			0.03381				
1204521	6799648	5.64511			0.00452				
1198344	7026681	5.86366			0.0229				
1761669	9986852	5.66897			0.00188				
1594787	9566998	5.99892			0.08214				
848947	4365740	5.14254			0.32466				



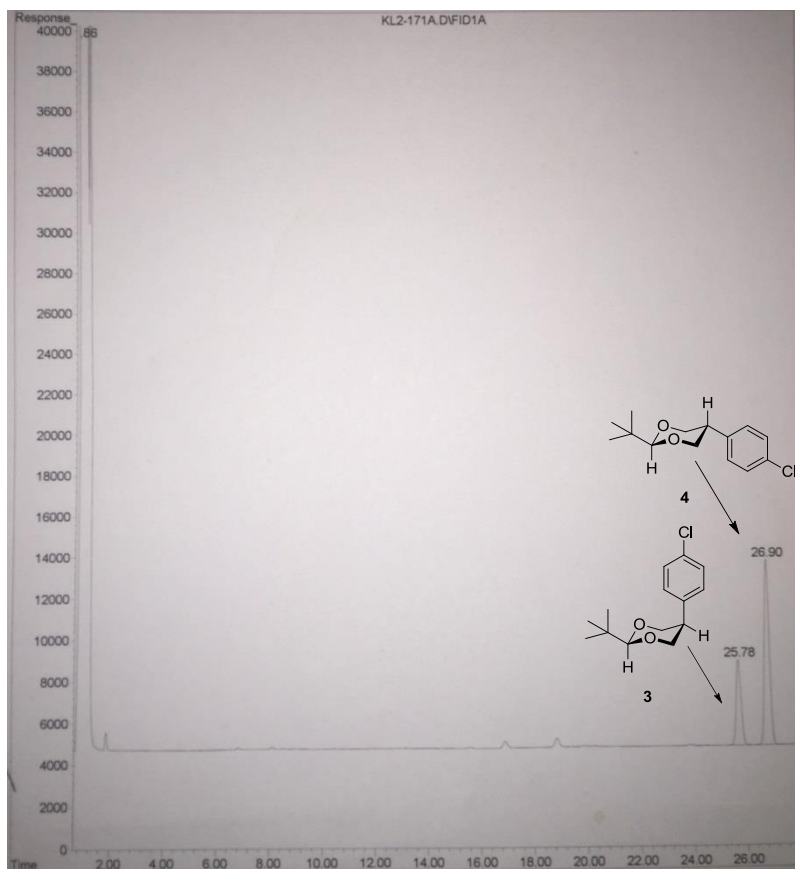
GC column: EC-1; 100% dimethyl polysiloxane; 30 meters; id- 0.25 mm; film- 0.25 μ m

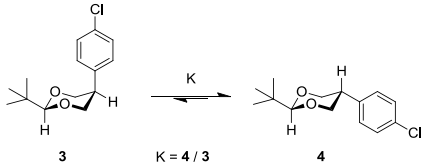


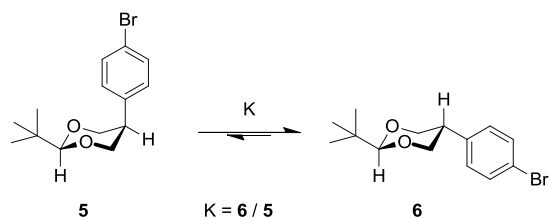
Program Description

The initial temperature was set at 100 °C for five minutes and increased at a rate of 2 °C/min and held at a final temperature of 170 °C for a period of 10 minutes.

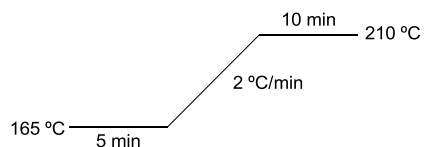
Compound	Ret. Time
3	25.78 min
4	26.90 min



									
Equilibrium study from 5-(4-chlorophenyl)- <i>cis</i> -2- <i>tert</i> -butyl-1,3-dioxane 3 in ether									
Area of axial aryl isomer (3)	Area of equatorial aryl isomer (4)	K	K _{Av}	Overall \bar{K}	$(K - \bar{K})^2$	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
4089137	13031747	3.18692	3.2163	3.2545237	0.00457	0.1212929	0.022480812	-0.694491441	-0.694±0.004 kcal/mol
5369092	17426588	3.24572			7.7E-05			-0.698542764	0.004051323
3362132	10499630	3.12291			0.01732			-0.690412036	-0.004079405
4635025	14752490	3.18283			0.00514				
3984310	12634562	3.17108			0.00696				
4820396	15871287	3.29253			0.00144				
3942604	12728011	3.22833			0.00069				
3700033	12063166	3.26029			3.3E-05				
3710841	12082785	3.25608			2.4E-06				
4539818	14932041	3.28913			0.0012				
Equilibrium study from 5-(4-chlorophenyl)- <i>trans</i> -2- <i>tert</i> -butyl-1,3-dioxane 4 in ether									
Area of axial aryl isomer (3)	Area of equatorial aryl isomer (4)	K	K _{Av}		$(K - \bar{K})^2$				
1242740	3846438	3.09513	3.3061		0.02541				
2779725	9471854	3.40748			0.0234				
2003935	6770126	3.37842			0.01535				
2499277	8134447	3.25472			3.9E-08				
2145942	7244770	3.37603			0.01476				
3834055	12747477	3.3248			0.00494				
Equilibrium study from 5-(4-chlorophenyl)- <i>cis</i> -2- <i>tert</i> -butyl-1,3-dioxane 3 in cyclohexane									
Area of axial aryl isomer (3)	Area of equatorial aryl isomer (4)	K	K _{Av}	Overall \bar{K}	$(K - \bar{K})^2$	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
8102841	25687704	3.17021	3.1758	3.1884024	0.00033	0.0052837	0.006326769	-0.682411305	-0.682±0.001 kcal/mol
5637540	17753154	3.1491			0.00155			-0.683577971	0.001166665
7829375	24963329	3.18842			2.8E-10			-0.681242323	-0.001168983
6506075	20644533	3.17312			0.00023				
6813601	21701727	3.18506			1.1E-05				
5917384	18703948	3.16085			0.00076				
Equilibrium study from 5-(4-chlorophenyl)- <i>trans</i> -2- <i>tert</i> -butyl-1,3-dioxane 4 in cyclohexane									
Area of axial aryl isomer (3)	Area of equatorial aryl isomer (4)	K	K _{Av}		$(K - \bar{K})^2$				
10246965	32839483	3.2048	3.2057		0.00027				
6902350	22227503	3.22028			0.00102				
6555915	21083449	3.21594			0.00076				
7358323	23700641	3.22093			0.00106				
4710057	14982918	3.18105			5.4E-05				
5221319	16661637	3.19108			7.2E-06				



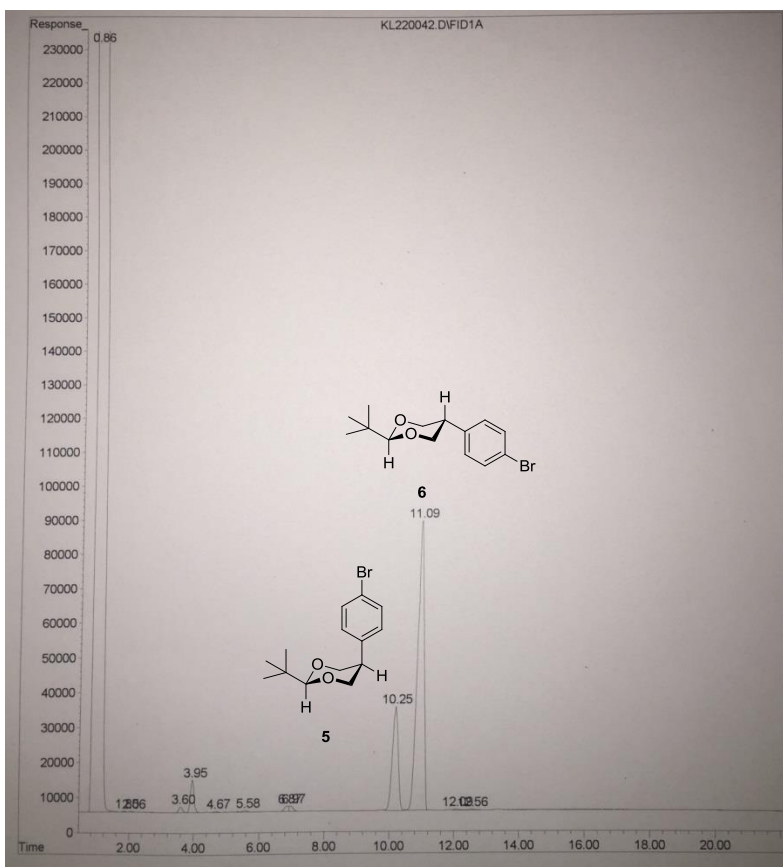
GC column: EC-1; 100% dimethyl polysiloxane; 30 meters; id- 0.25 mm; film- 0.25 μ m

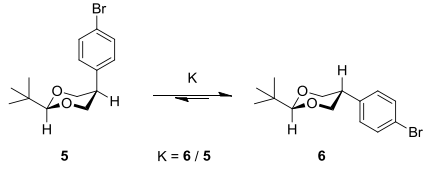


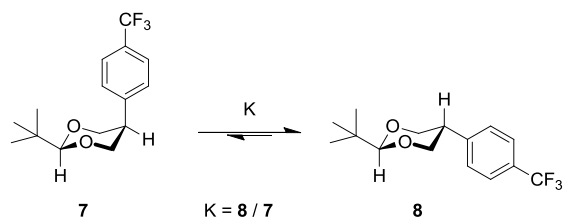
Program Description

The initial temperature was set at 165 °C for five minutes and increased at a rate of 2 °C/min and held at a final temperature of 210 °C for a period of 10 minutes.

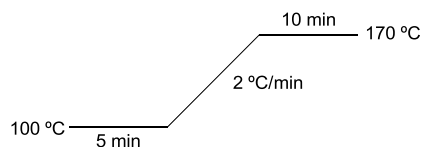
Compound	Ret. Time
5	10.25 min
6	11.09 min



									
Equilibrium study from 5-(4-bromophenyl)- <i>cis</i> -2- <i>tert</i> -butyl-1,3-dioxane 5 in ether									
Area of axial aryl isomer (5)	Area of equatorial aryl isomer (6)	K	K _{Av}	Overall \bar{K}	$(K - \bar{K})^2$	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
1952038	6458986	3.30884	3.2457	3.1940636	0.01317	0.0446184	0.022265663	-0.683455342	-0.683 +/- 0.004 kcal/mol
1401067	4530151	3.23336			0.00154			-0.687543717	0.004088375
1497874	4859754	3.24443			0.00254			-0.679338368	-0.004116975
1256275	4048612	3.22271			0.00082				
1322898	4258695	3.21922			0.00063				
Equilibrium study from 5-(4-bromophenyl)- <i>trans</i> -2- <i>tert</i> -butyl-1,3-dioxane 6 in ether									
Area of axial aryl isomer (5)	Area of equatorial aryl isomer (6)	K	K _{Av}		$(K - \bar{K})^2$				
1598803	4942515	3.09138	3.1424		0.01054				
2240564	7129989	3.18223			0.00014				
1577189	4844606	3.07167			0.01498				
2179419	6931237	3.18031			0.00019				
2256676	7190838	3.18647			5.8E-05				
Equilibrium study from 5-(4-bromophenyl)- <i>cis</i> -2- <i>tert</i> -butyl-1,3-dioxane 5 in cyclohexane									
Area of axial aryl isomer (5)	Area of equatorial aryl isomer (6)	K	K _{Av}	Overall \bar{K}	$(K - \bar{K})^2$	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
4279305	13225049	3.09047	3.0664	3.0672863	0.00054	0.0130937	0.01206174	-0.659619491	-0.659 +/- 0.002 kcal/mol
5489664	16706166	3.0432			0.00058			-0.661929274	-0.002309783
5574804	17424919	3.12566			0.00341			-0.657300608	-0.002318883
5112244	15469474	3.02597			0.00171				
5875639	17902570	3.04691			0.00042				
Equilibrium study from 5-(4-bromophenyl)- <i>trans</i> -2- <i>tert</i> -butyl-1,3-dioxane 6 in cyclohexane									
Area of axial aryl isomer (5)	Area of equatorial aryl isomer (6)	K	K _{Av}		$(K - \bar{K})^2$				
3870826	11982579	3.09561	3.0589		0.0008				
5861792	17849287	3.04502			0.0005				
5103425	15847925	3.10535			0.00145				
6015796	18212128	3.02738			0.00159				
6148087	18575677	3.02138			0.00211				



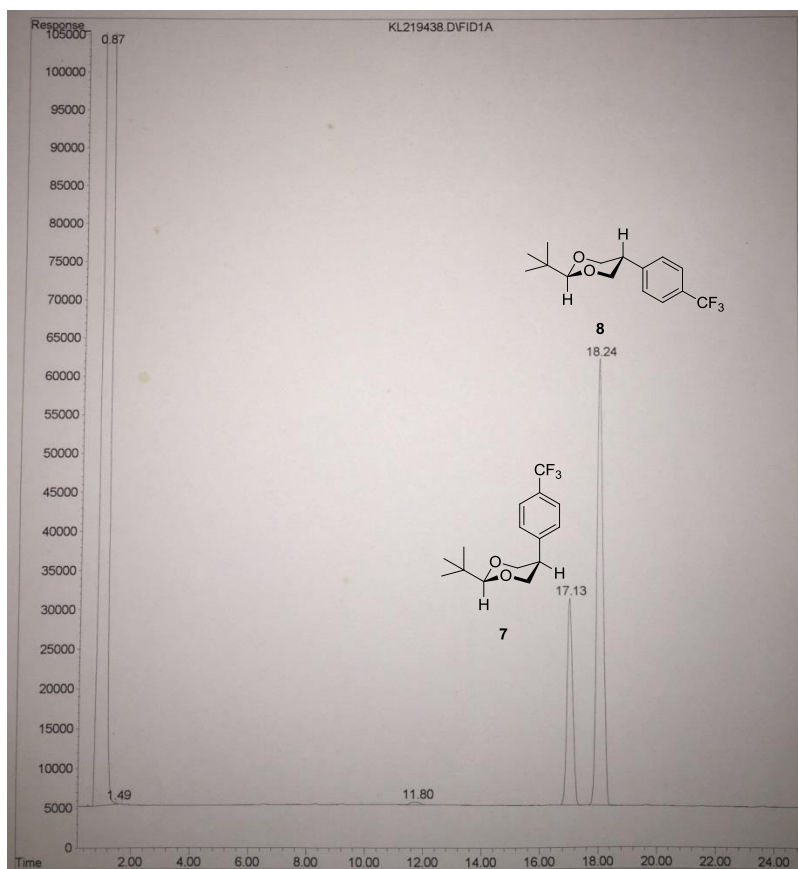
GC column: EC-1; 100% dimethyl polysiloxane; 30 meters; id- 0.25 mm; film- 0.25 μ m



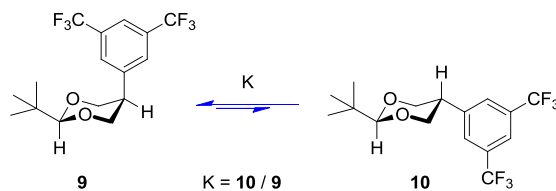
Program Description

The initial temperature was set at 100 °C for five minutes and increased at a rate of 2 °C/min and held at a final temperature of 170 °C for a period of 10 minutes.

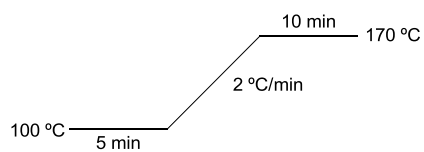
Compound	Ret. Time
7	17.13 min
8	18.23 min



<div style="text-align: center;"> <p>7 \xrightleftharpoons{K} 8 K = 8 / 7</p> </div>									
Equilibrium study from 5-(4-(trifluoromethyl)phenyl)- <i>cis</i> -2- <i>tert</i> -butyl-1,3-dioxane 7 in ether									
Area of axial aryl isomer (7)	Area of equatorial aryl isomer (8)	K	K _{Av}	Overall \bar{K}	(K - \bar{K}) ²	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
10736824	32680727	3.0438	3.0849	3.0984999	0.00299	0.0165837	0.010310475	-0.665578274	-0.665 +/- 0.002
15537344	48131204	3.09778			5.2E-07			-0.667533394	0.001955121
15033849	46763287	3.11053			0.00014			-0.663616636	-0.001961637
32874959	100850973	3.06771			0.00095				
13165226	41069869	3.11957			0.00044				
15748470	48384554	3.07233			0.00068				
4845626	14936928	3.08256			0.00025				
Equilibrium study from 5-(4-(trifluoromethyl)phenyl)- <i>trans</i> -2- <i>tert</i> -butyl-1,3-dioxane 8 in ether									
Area of axial aryl isomer (7)	Area of equatorial aryl isomer (8)	K	K _{Av}		(K - \bar{K}) ²				
10368913	32674052	3.15115	3.1144		0.00277				
12863940	40565504	3.15343			0.00302				
11906452	37602843	3.15819			0.00356				
9745036	29966258	3.07503			0.00055				
11837439	36437841	3.07819			0.00041				
12320531	37826820	3.07023			0.0008				
Equilibrium study from 5-(4-(trifluoromethyl)phenyl)- <i>cis</i> -2- <i>tert</i> -butyl-1,3-dioxane 7 in cyclohexane									
Area of axial aryl isomer (7)	Area of equatorial aryl isomer (8)	K	K _{Av}	Overall \bar{K}	(K - \bar{K}) ²	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
23753303	55447358	2.3343	2.3317	2.3102977	0.00058	0.0511847	0.019691688	-0.492820421	-0.493 +/- 0.005 kcal/mol
13130588	30917965	2.35465			0.00197			-0.497815457	0.004995037
3718310	8618468	2.31785			5.7E-05			-0.487782627	-0.005037794
3682123	8517744	2.31327			8.8E-06				
3151350	7362966	2.33645			0.00068				
2888254	6741134	2.33398			0.00056				
Equilibrium study from 5-(4-(trifluoromethyl)phenyl)- <i>trans</i> -2- <i>tert</i> -butyl-1,3-dioxane 8 in cyclohexane									
Area of axial aryl isomer (7)	Area of equatorial aryl isomer (8)	K	K _{Av}		(K - \bar{K}) ²				
12880751	30397134	2.35989	2.2829		0.00246				
3403545	7355237	2.16105			0.02227				
30064462	70287404	2.33789			0.00076				
7308001	17411671	2.38255			0.00522				
3231149	7350088	2.27476			0.00126				
3871654	8445614	2.1814			0.01662				



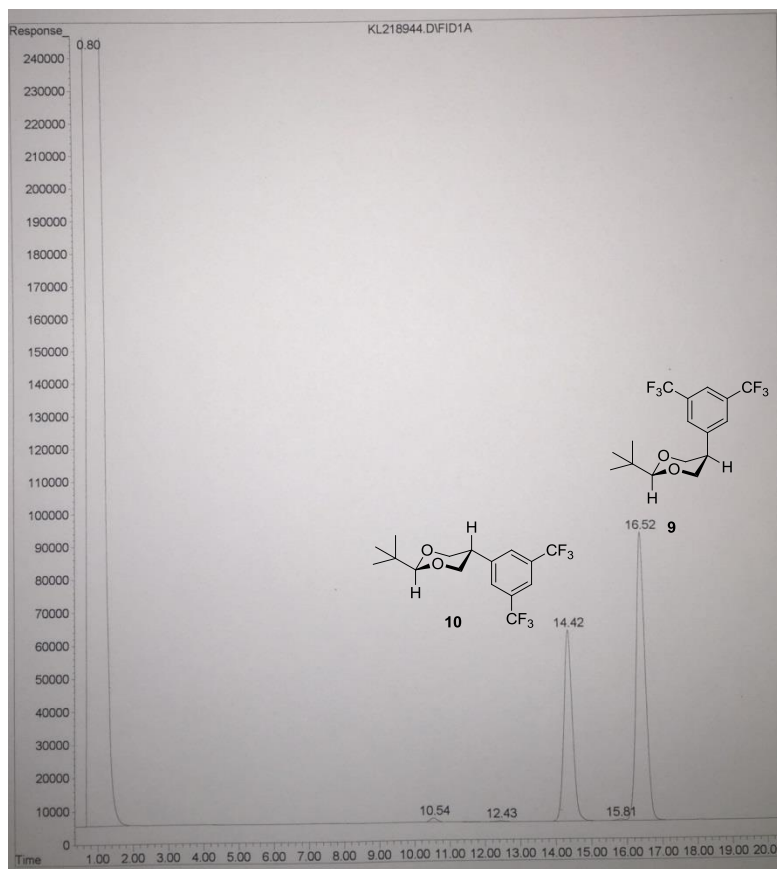
GC column: Optima[®] 225; 50% cyanopropyl, 50% phenylmethyl polysiloxane; 30 meters; id- 0.25 mm; film- 0.25 μ m

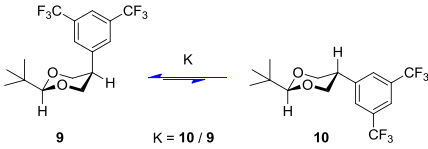


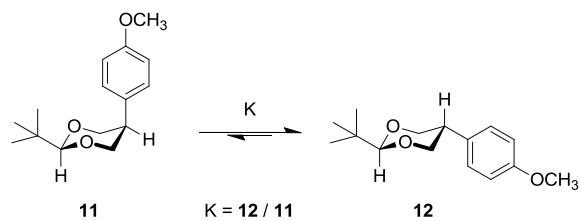
Program Description

The initial temperature was set at 100 °C for five minutes and increased at a rate of 2 °C/min and held at a final temperature of 170 °C for a period of 10 minutes.

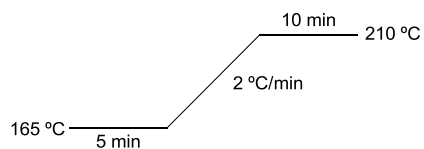
Compound	Ret. Time
9	16.52 min
10	14.42 min



									
Equilibrium study from 5-(3,5-bis-trifluoromethylphenyl)- <i>cis</i> -2- <i>tert</i> -butyl-1,3-dioxane 9 in acetonitrile									
Area of axial aryl isomer (9)	Area of equatorial aryl isomer (10)	K	K _{Av}	Overall \bar{K}	$(K - \bar{K})^2$	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
18744878	12772173	0.68137	0.6891	0.6850139	1.3E-05	0.0005776	0.002533251	0.222650076	0.223 +/- 0.002 kcal/mol
17065062	11723089	0.68696			3.8E-06			0.22047765	-0.002172426
4704284	3324698	0.70674			0.00047			0.224830552	-0.002180475
18334995	12557560	0.6849			1.4E-08				
17280832	11847696	0.6856			3.4E-07				
Equilibrium study from 5-(3,5-bis-trifluoromethylphenyl)- <i>trans</i> -2- <i>tert</i> -butyl-1,3-dioxane 10 in acetonitrile									
Area of axial aryl isomer (9)	Area of equatorial aryl isomer (10)	K	K _{Av}		$(K - \bar{K})^2$				
21063877	14350192	0.68127	0.6809		1.4E-05				
15106978	10308572	0.68237			7E-06				
20372111	13873779	0.68102			1.6E-05				
22145000	15061508	0.68013			2.4E-05				
21224362	14427962	0.67978			2.7E-05				
Equilibrium study from 5-(3,5-bis-trifluoromethylphenyl)- <i>cis</i> -2- <i>tert</i> -butyl-1,3-dioxane 9 in cyclohexane									
Area of axial aryl isomer (9)	Area of equatorial aryl isomer (10)	K	K _{Av}	Overall \bar{K}	$(K - \bar{K})^2$	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
14243377	9369803	0.65784	0.6348	0.6338609	0.00057	0.0014736	0.003660133	0.268325614	0.268 +/- 0.003 kcal/mol
15065738	9582776	0.63606			4.9E-06			0.264937016	0.003388597
15662903	9489285	0.60584			0.00078			0.271733835	-0.003408221
15275603	9706851	0.63545			2.5E-06				
15742685	10060404	0.63905			2.7E-05				
14835932	9417597	0.63478			8.5E-07				
Equilibrium study from 5-(3,5-bis-trifluoromethylphenyl)- <i>trans</i> -2- <i>tert</i> -butyl-1,3-dioxane 10 in cyclohexane									
Area of axial aryl isomer (9)	Area of equatorial aryl isomer (10)	K	K _{Av}		$(K - \bar{K})^2$				
17035841	10654565	0.62542	0.6327		7.1E-05				
15316510	9737326	0.63574			3.5E-06				
15856744	10058172	0.63432			2.1E-07				
14854607	9437846	0.63535			2.2E-06				
15614352	9877910	0.63262			1.5E-06				



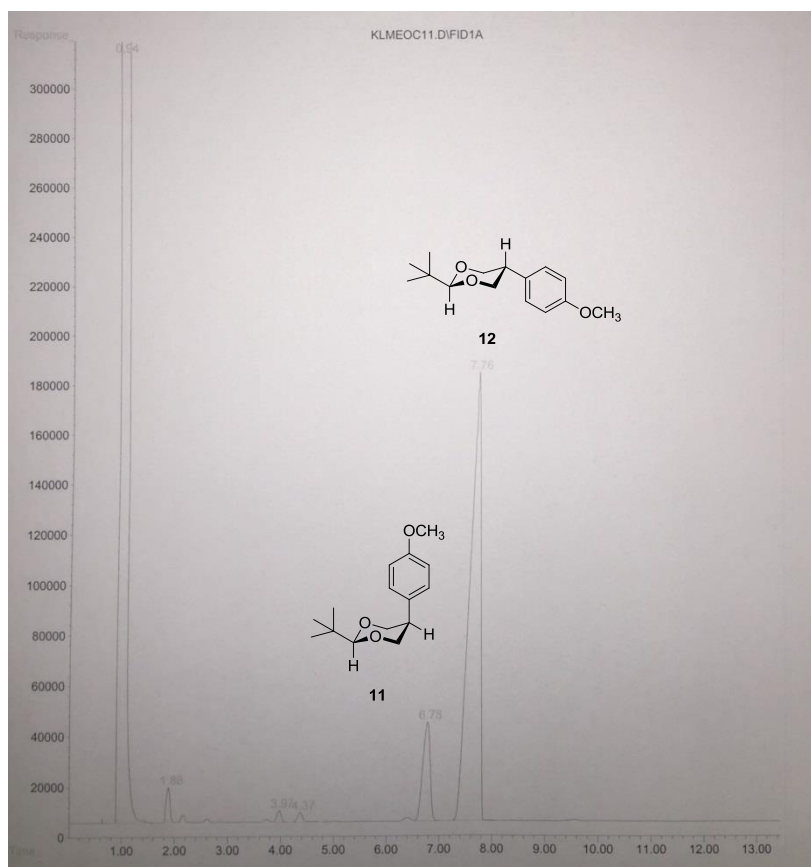
GC column: EC-1; 100% dimethyl polysiloxane; 30 meters; id- 0.25 mm; film- 0.25 μ m

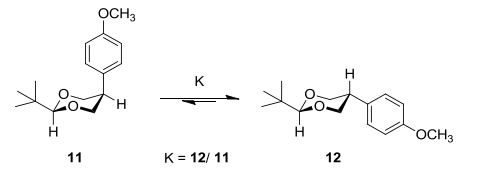


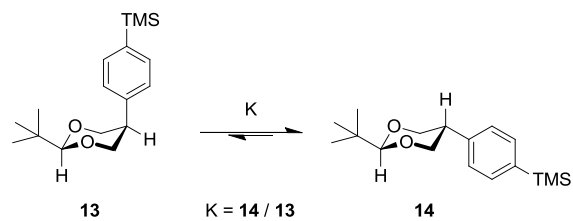
Program Description

The initial temperature was set at 165 °C for five minutes and increased at a rate of 2 °C/min and held at a final temperature of 210 °C for a period of 10 minutes.

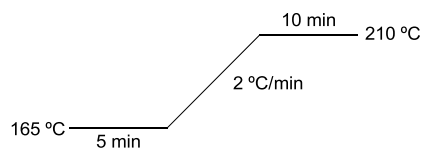
Compound	Ret. Time
11	6.78 min
12	7.76 min



									
Equilibrium study from 5-(4-methoxyphenyl)- <i>cis</i> -2- <i>tert</i> -butyl-1,3-dioxane 11 in ether									
Area of axial aryl isomer (11)	Area of equatorial aryl isomer (12)	K	K _{Av}	Overall \bar{K}	$(K - \bar{K})^2$	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
717288	4159475	5.79889	5.7029	5.7300384	0.00474	0.1987472	0.035693421	-1.027408427	-1.027±0.004 kcal/mol
681815	3848317	5.64422			0.00736			-1.031063108	0.003654681
797780	4487155	5.62455			0.01113			-1.023730909	-0.003677518
851553	4976543	5.84408			0.01301				
726963	4177085	5.74594			0.00025				
679852	3593049	5.28505			0.19802				
625952	3538432	5.65288			0.00595				
925318	5577474	6.02763			0.08856				
Equilibrium study from 5-(4-methoxyphenyl)- <i>trans</i> -2- <i>tert</i> -butyl-1,3-dioxane 12 in ether									
Area of axial aryl isomer (11)	Area of equatorial aryl isomer (12)	K	K _{Av}		$(K - \bar{K})^2$				
548021	3223178	5.88149	5.6921		0.02294				
505894	2827194	5.58851			0.02003				
622226	3579549	5.75281			0.00052				
675524	3807728	5.6367			0.00871				
684893	3848083	5.61852			0.01244				
695913	3948802	5.67428			0.00311				
Equilibrium study from 5-(4-methoxyphenyl)- <i>cis</i> -2- <i>tert</i> -butyl-1,3-dioxane 11 in cyclohexane									
Area of axial aryl isomer (11)	Area of equatorial aryl isomer (12)	K	K _{Av}	Overall \bar{K}	$(K - \bar{K})^2$	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
2287046	14161637	6.19211	6.3681	6.3506918	0.02515	0.2913422	0.017137437	-1.08793366	-1.088±0.002 kcal/mol
2352098	14537349	6.18059			0.02894			-1.089519675	-0.001586016
3132782	19586183	6.25201			0.00974			-1.086343358	-0.001590301
3161622	19717703	6.23658			0.01302				
3336497	21066571	6.31398			0.00135				
3055003	19241550	6.29837			0.00274				
4956870	32116696	6.47923			0.01652				
12776995	83870521	6.56418			0.04558				
5008418	32315368	6.45221			0.01031				
2798785	18158516	6.488			0.01885				
3823811	23999726	6.27639			0.00552				
3462066	22301310	6.44162			0.00827				
3473799	22582224	6.50073			0.02251				
3549349	22660580	6.38443			0.00114				
3518037	22536808	6.40607			0.00307				
3967643	25486097	6.42349			0.0053				
Equilibrium study from 5-(4-methoxyphenyl)- <i>trans</i> -2- <i>tert</i> -butyl-1,3-dioxane 12 in cyclohexane									
Area of axial aryl isomer (11)	Area of equatorial aryl isomer (12)	K	K _{Av}		$(K - \bar{K})^2$				
2592206	16113969	6.21631	6.3321		0.01806				
4018363	25439446	6.3308			0.0004				
2211206	13898605	6.28553			0.00425				
2888246	18055462	6.25136			0.00987				
2740298	17054892	6.22374			0.01612				
17948736	113885709	6.34505			3.2E-05				
19569063	123853253	6.32903			0.00047				
20055377	126646738	6.31485			0.00128				
23333392	147782999	6.33354			0.00029				
19378757	122247524	6.30833			0.00179				
4728192	30140266	6.37459			0.00057				
4671037	29827553	6.38564			0.00122				
5173120	33116027	6.40156			0.00259				
4556923	29400896	6.45192			0.01025				
4442629	28562599	6.42921			0.00617				



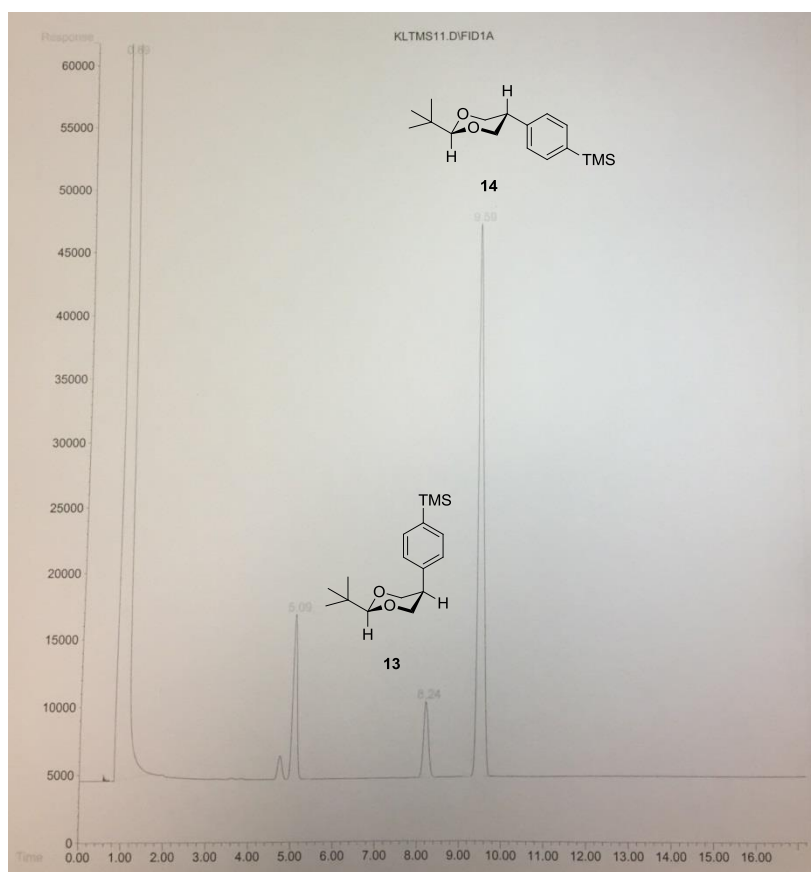
GC column: EC-1; 100% dimethyl polysiloxane; 30 meters; id- 0.25 mm; film- 0.25 μm



Program Description

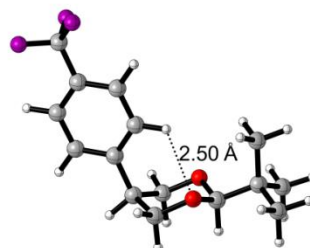
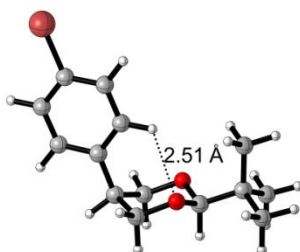
The initial temperature was set at 165 °C for five minutes and increased at a rate of 2 °C/min and held at a final temperature of 210 °C for a period of 10 minutes.

Compound	Ret. Time
13	8.24 min
14	9.59 min



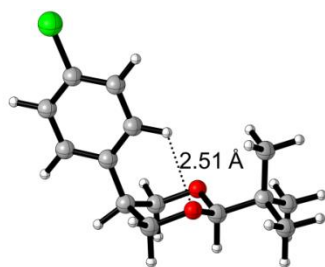
<div style="text-align: center;"> <p>13 \xrightleftharpoons{K} 14 K = 14 / 13</p> </div>									
Equilibrium study from 5-(4-trimethylsilylphenyl)- <i>cis</i> -2- <i>tert</i> -butyl-1,3-dioxane 13 in ether									
Area of axial aryl isomer (13)	Area of equatorial aryl isomer (14)	K	K _{Av}	Overall \bar{K}	$(K - \bar{K})^2$	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
919895	6070952	6.59961	6.6326	6.6995244	0.00998	4.6996283	0.13993493	-1.119403947	-1.12±0.01 kcal/mol
1005217	6485506	6.45185			0.06134			-1.131570107	0.01216616
564707	3213939	5.69134			1.01644			-1.106980968	-0.01242298
620282	3969443	6.39942			0.09006				
696634	4911818	7.05079			0.12339				
606146	4062977	6.70297			1.2E-05				
755171	5350495	7.08514			0.1487				
823954	5404995	6.55983			0.01952				
811391	5803790	7.15289			0.20554				
Equilibrium study from 5-(4-trimethylsilylphenyl)- <i>trans</i> -2- <i>tert</i> -butyl-1,3-dioxane 14 in ether									
Area of axial aryl isomer (13)	Area of equatorial aryl isomer (14)	K	K _{Av}		$(K - \bar{K})^2$				
305652	2340576	7.65765	6.7855		0.918				
1010581	7993183	7.90949			1.46402				
775053	5039104	6.50163			0.03916				
745992	4942553	6.62548			0.00548				
936853	5877718	6.2739			0.18116				
733056	4695836	6.40584			0.08625				
325934	1996210	6.12458			0.33056				
Equilibrium study from 5-(4-trimethylsilylphenyl)- <i>cis</i> -2- <i>tert</i> -butyl-1,3-dioxane 13 in cyclohexane									
Area of axial aryl isomer (13)	Area of equatorial aryl isomer (14)	K	K _{Av}	Overall \bar{K}	$(K - \bar{K})^2$	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
200815	1400591	6.97453	7.221	7.1703658	0.03835	11.032166	0.214399998	-1.159376931	-1.16±0.02 kcal/mol
199429	1205161	6.04306			1.27082			-1.176716489	0.017339558
326089	2359832	7.23677			0.00441			-1.141510956	-0.017865974
298873	2235916	7.48116			0.09659				
235642	2003638	8.50289			1.77562				
210861	1849462	8.771			2.56203				
236309	1471065	6.22518			0.89338				
166839	1205947	7.22821			0.00335				
184007	1200799	6.52583			0.41542				
Equilibrium study from 5-(4-trimethylsilylphenyl)- <i>trans</i> -2- <i>tert</i> -butyl-1,3-dioxane 14 in cyclohexane									
Area of axial aryl isomer (13)	Area of equatorial aryl isomer (14)	K	K _{Av}		$(K - \bar{K})^2$				
358502	2054798	5.73162	7.1053		2.06998				
142984	1073030	7.50455			0.11168				
141096	1043932	7.39874			0.05215				
142678	1082543	7.58732			0.17385				
143026	1128415	7.88958			0.51727				
189197	1169929	6.18366			0.9736				
145096	1079771	7.44177			0.07366				

Calculated Lowest Energy Geometries at the B3LYP/6-311+G* Level and X,Y,Z Coordinates of the Atoms

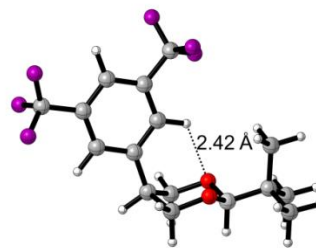


0.8737	1.9557	-0.0981	C
3.1916	0.2978	0.0088	C
3.9136	1.1360	0.0033	H
1.7164	1.7074	1.1727	C
1.1003	1.7209	2.0721	H
2.4788	2.4967	1.2630	H
1.7668	1.6287	-1.3118	C
2.5259	2.4176	-1.4257	H
1.1886	1.5749	-2.2346	H
2.4225	0.3698	-1.1764	O
2.3601	0.4385	1.1438	O
0.6700	3.0327	-0.1351	H
-0.4651	1.2417	-0.0851	C
-1.6345	1.9801	0.1311	C
-0.5883	-0.1421	-0.2670	C
-2.8887	1.3730	0.1701	C
-1.5735	3.0561	0.2706	H
-1.8343	-0.7655	-0.2336	C
0.2951	-0.7420	-0.4404	H
-2.9758	-0.0019	-0.0131	C
-3.7806	1.9650	0.3372	H
-1.9112	-1.8367	-0.3774	H
3.9505	-1.0389	0.0687	C
4.7956	-1.0595	1.3551	C
4.1689	-1.0139	2.2470	H
5.3879	-1.9779	1.4009	H
5.4940	-0.2165	1.3905	H
4.8787	-1.1265	-1.1560	C
5.5864	-0.2911	-1.1843	H
5.4633	-2.0502	-1.1195	H
4.3129	-1.1192	-2.0890	H
2.9697	-2.2237	0.0685	C
2.2883	-2.1757	0.9203	H
2.3757	-2.2472	-0.8477	H
3.5215	-3.1663	0.1319	H
-4.6944	-0.8568	0.0347	Br

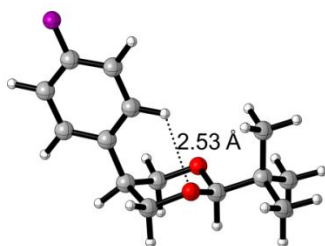
0.7945	1.9588	-0.0875	C
3.1252	0.3184	0.0163	C
3.8392	1.1632	0.0251	H
1.6308	1.7020	1.1866	C
1.0093	1.7012	2.0824	H
2.3854	2.4970	1.2896	H
1.6975	1.6511	-1.2994	C
2.4495	2.4484	-1.3997	H
1.1257	1.6027	-2.2266	H
2.3625	0.3971	-1.1730	O
2.2840	0.4392	1.1469	O
0.5815	3.0341	-0.1137	H
-0.5367	1.2321	-0.0888	C
-1.7143	1.9597	0.1231	C
-0.6423	-0.1522	-0.2825	C
-2.9584	1.3370	0.1469	C
-1.6622	3.0350	0.2675	H
-1.8823	-0.7824	-0.2627	C
0.2494	-0.7388	-0.4561	H
-3.0445	-0.0405	-0.0483	C
-3.8560	1.9231	0.3061	H
-1.9438	-1.8530	-0.4212	H
3.8954	-1.0120	0.0662	C
4.7316	-1.0397	1.3583	C
4.0984	-1.0106	2.2464	H
5.3319	-1.9531	1.3976	H
5.4220	-0.1909	1.4086	H
4.8330	-1.0766	-1.1528	C
5.5333	-0.2347	-1.1662	H
5.4257	-1.9953	-1.1228	H
4.2740	-1.0637	-2.0898	H
2.9256	-2.2056	0.0452	C
2.2381	-2.1744	0.8930	H
2.3384	-2.2242	-0.8754	H
3.4857	-3.1437	0.1015	H
-4.3756	-0.7329	0.0255	C
-5.3995	0.0797	-0.3249	F
-4.4363	-1.8180	-0.7807	F
-4.6503	-1.1745	1.2817	F



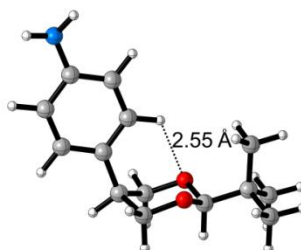
0.0770	1.8451	-0.1101	C
2.5282	0.3925	0.0032	C
3.1755	1.2896	-0.0115	H
0.9409	1.6804	1.1600	C
0.3279	1.6487	2.0610	H
1.6334	2.5327	1.2419	H
0.9915	1.5850	-1.3239	C
1.6800	2.4348	-1.4474	H
0.4174	1.4737	-2.2442	H
1.7530	0.3881	-1.1801	O
1.6906	0.4710	1.1396	O
-0.2176	2.9006	-0.1554	H
-1.1964	1.0201	-0.0863	C
-2.4230	1.6573	0.1358	C
-1.2030	-0.3699	-0.2632	C
-3.6201	0.9460	0.1850	C
-2.4524	2.7350	0.2718	H
-2.3911	-1.0961	-0.2195	C
-0.2729	-0.8931	-0.4409	H
-3.5918	-0.4318	0.0064	C
-4.5606	1.4564	0.3561	H
-2.3827	-2.1708	-0.3592	H
-5.0953	-1.3466	0.0631	Cl
3.3996	-0.8734	0.0719	C
4.2456	-0.8103	1.3563	C
3.6189	-0.8116	2.2494	H
4.9151	-1.6738	1.4080	H
4.8687	0.0900	1.3830	H
4.3296	-0.8907	-1.1543	C
4.9631	0.0020	-1.1908	H
4.9914	-1.7606	-1.1124	H
3.7636	-0.9391	-2.0860	H
2.5247	-2.1382	0.0836	C
1.8428	-2.1419	0.9364	H
1.9336	-2.2206	-0.8311	H
3.1557	-3.0293	0.1537	H



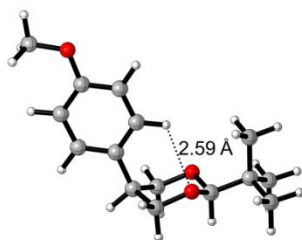
-0.6260	-2.0229	0.5025	C
-3.2622	-1.0344	0.0536	C
-3.7652	-2.0029	0.2314	H
-1.6304	-1.6892	1.6233	C
-1.1307	-1.3149	2.5175	H
-2.1813	-2.6020	1.8947	H
-1.4415	-2.2543	-0.7905	C
-1.9907	-3.2044	-0.7048	H
-0.7984	-2.3088	-1.6693	H
-2.3606	-1.1968	-1.0254	O
-2.5571	-0.6812	1.2301	O
-0.1592	-2.9805	0.7614	H
0.4856	-1.0060	0.3238	C
1.7963	-1.4532	0.1360	C
0.2503	0.3739	0.3177	C
2.8438	-0.5530	-0.0567	C
2.0062	-2.5178	0.1388	H
1.3015	1.2701	0.1298	C
-0.7539	0.7452	0.4696	H
2.6048	0.8178	-0.0616	C
3.4164	1.5183	-0.2074	H
-4.3082	0.0411	-0.2832	C
-5.2919	0.1472	0.8960	C
-4.7894	0.4660	1.8105	H
-6.0746	0.8758	0.6669	H
-5.7839	-0.8105	1.0971	H
-5.0680	-0.4035	-1.5462	C
-5.5451	-1.3793	-1.4063	H
-5.8571	0.3162	-1.7815	H
-4.4046	-0.4741	-2.4096	H
-3.6355	1.4021	-0.5292	C
-3.1152	1.7584	0.3624	H
-2.9176	1.3504	-1.3502	H
-4.3902	2.1493	-0.7916	H
4.2487	-1.0761	-0.1970	C
1.0077	2.7474	0.0800	C
4.2923	-2.2238	-0.9132	F
5.0681	-0.1937	-0.8052	F
2.0935	3.4951	0.3765	F
0.5935	3.1337	-1.1526	F
0.0311	3.1005	0.9443	F
4.8020	-1.3565	1.0104	F



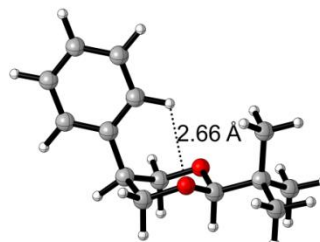
-0.4188	-1.7132	0.1039	C
2.1515	-0.4819	0.0046	C
2.7174	-1.4323	0.0284	H
0.4652	-1.6304	-1.1600	C
-0.1363	-1.5476	-2.0655	H
1.0806	-2.5405	-1.2346	H
0.5067	-1.5299	1.3235	C
1.1186	-2.4355	1.4546	H
-0.0619	-1.3657	2.2392	H
1.3703	-0.4039	1.1814	O
1.3194	-0.4917	-1.1384	O
-0.8042	-2.7390	0.1510	H
-1.6165	-0.7812	0.0716	C
-2.8971	-1.3163	-0.1144	C
-1.4975	0.6092	0.2077	C
-4.0296	-0.5051	-0.1678	C
-3.0202	-2.3907	-0.2184	H
-2.6182	1.4359	0.1593	C
-0.5220	1.0516	0.3568	H
-3.8653	0.8625	-0.0295	C
-5.0205	-0.9210	-0.3100	H
-2.5303	2.5113	0.2654	H
3.1312	0.7023	-0.0621	C
3.9800	0.5580	-1.3380	C
3.3636	0.6073	-2.2369	H
4.7219	1.3601	-1.3887	H
4.5232	-0.3929	-1.3537	H
4.0482	0.6453	1.1728	C
4.6006	-0.2993	1.2197	H
4.7840	1.4536	1.1325	H
3.4802	0.7486	2.0987	H
2.3707	2.0389	-0.0884	C
1.7014	2.0982	-0.9492	H
1.7789	2.1767	0.8191	H
3.0781	2.8709	-0.1546	H
-4.9593	1.6651	-0.0775	F



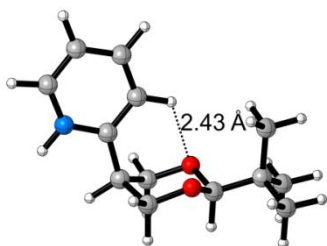
-0.3882	-1.7216	-0.0975	C
2.1734	-0.4714	-0.0017	C
2.7485	-1.4169	-0.0221	H
0.5372	-1.5370	-1.3166	C
-0.0328	-1.3790	-2.2324	H
1.1576	-2.4375	-1.4456	H
0.4953	-1.6293	1.1654	C
1.1185	-2.5341	1.2454	H
-0.1079	-1.5463	2.0697	H
1.3436	-0.4844	1.1420	O
1.3939	-0.4036	-1.1788	O
-0.7630	-2.7520	-0.1411	H
-1.5966	-0.8043	-0.0720	C
-2.8744	-1.3455	0.1103	C
-1.5057	0.5876	-0.2100	C
-4.0132	-0.5473	0.1573	C
-2.9898	-2.4213	0.2173	H
-2.6372	1.3946	-0.1667	C
-0.5377	1.0489	-0.3560	H
-3.9122	0.8427	0.0207	C
-4.9889	-1.0071	0.2912	H
-2.5314	2.4700	-0.2847	H
3.1433	0.7217	0.0612	C
4.0606	0.6694	-1.1735	C
3.4911	0.7642	-2.0994	H
4.7893	1.4845	-1.1362	H
4.6213	-0.2705	-1.2177	H
3.9937	0.5896	1.3373	C
4.5457	-0.3563	1.3558	H
4.7282	1.3989	1.3858	H
3.3765	0.6353	2.2359	H
2.3704	2.0511	0.0833	C
1.7757	2.1788	-0.8237	H
1.7009	2.1062	0.9440	H
3.0700	2.8904	0.1457	H
-5.0555	1.6510	0.0059	N
-5.8592	1.2712	0.4850	H
-4.9020	2.6185	0.2510	H



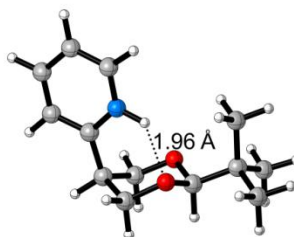
-0.0637	1.7837	0.0598	C
-2.5676	0.4199	-0.0078	C
-3.1818	1.3406	-0.0051	H
-0.9405	1.6243	-1.2009	C
-0.3335	1.5476	-2.1033	H
-1.6011	2.5000	-1.3006	H
-0.9801	1.5814	1.2837	C
-1.6399	2.4560	1.3946	H
-0.4037	1.4682	2.2021	H
-1.7840	0.4086	1.1688	O
-1.7392	0.4453	-1.1527	O
0.2639	2.8305	0.0822	H
1.1850	0.9218	0.0564	C
2.4390	1.5229	-0.0592	C
1.1470	-0.4795	0.1563	C
3.6222	0.7792	-0.0789	C
2.5095	2.6050	-0.1356	H
2.3114	-1.2328	0.1401	C
0.1947	-0.9840	0.2505	H
3.5598	-0.6110	0.0210	C
4.5697	1.2957	-0.1692	H
2.2760	-2.3141	0.2186	H
-3.4864	-0.8138	-0.0453	C
-4.3443	-0.7416	-1.3211	C
-3.7278	-0.7785	-2.2206	H
-5.0439	-1.5820	-1.3521	H
-4.9359	0.1795	-1.3558	H
-4.4024	-0.7758	1.1911	C
-5.0008	0.1411	1.2197	H
-5.0974	-1.6204	1.1707	H
-3.8276	-0.8307	2.1169	H
-2.6590	-2.1102	-0.0440	C
-1.9938	-2.1572	-0.9086	H
-2.0537	-2.1935	0.8611	H
-3.3234	-2.9787	-0.0832	H
4.6449	-1.4421	0.0143	O
5.9361	-0.8684	-0.1047	C
6.6359	-1.7021	-0.0896	H
6.0469	-0.3213	-1.0473	H
6.1561	-0.1974	0.7328	H



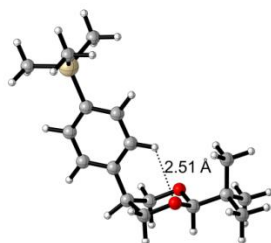
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1.7721	-0.5600	0.0000	C
2.2282	-1.5682	0.0002	H
-0.0041	-1.4691	-1.2432	C
-0.5738	-1.2802	-2.1533	H
0.5074	-2.4385	-1.3494	H
-0.0040	-1.4688	1.2437	C
0.5075	-2.4381	1.3500	H
-0.5737	-1.2797	2.1538	H
0.9742	-0.4360	1.1607	O
0.9742	-0.4363	-1.1606	O
-1.4073	-2.4895	0.0004	H
-2.0129	-0.4569	0.0001	C
-3.3534	-0.8627	-0.0002	C
-1.7392	0.9182	0.0004	C
-4.3918	0.0678	-0.0004	C
-3.5910	-1.9234	-0.0004	H
-2.7757	1.8498	0.0002	C
-0.7128	1.2592	0.0007	H
-4.1054	1.4309	-0.0002	C
-5.4222	-0.2741	-0.0007	H
-2.5412	2.9099	0.0004	H
-4.9097	2.1597	-0.0003	H
2.8796	0.5078	-0.0001	C
3.7451	0.3090	-1.2571	C
3.1637	0.4497	-2.1696	H
4.5700	1.0274	-1.2643	H
4.1833	-0.6943	-1.2883	H
3.7459	0.3084	1.2562	C
4.1842	-0.6950	1.2866	H
4.5709	1.0268	1.2633	H
3.1651	0.4487	2.1692	H
2.2743	1.9216	0.0004	C
1.6577	2.0895	-0.8851	H
1.6584	2.0892	0.8864	H
3.0722	2.6705	0.0001	H



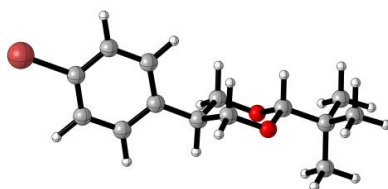
0.9167	-1.5392	0.1213	C
-1.7665	-0.5672	0.0066	C
-2.2308	-1.5667	0.0296	H
-0.0388	-1.4548	1.3415	C
0.4980	-1.2603	2.2708	H
-0.5497	-2.4224	1.4380	H
0.0223	-1.5556	-1.1544	C
-0.4915	-2.5262	-1.1912	H
0.6074	-1.4452	-2.0686	H
-0.9106	-0.5000	-1.1295	O
-0.9812	-0.4133	1.1839	O
1.4469	-2.4983	0.1727	H
1.9279	-0.4302	0.0830	C
1.6433	0.9291	0.2171	C
2.6669	1.8665	0.1367	C
0.6193	1.2275	0.3870	H
4.2495	0.1182	-0.2057	C
3.9891	1.4626	-0.0797	C
2.4357	2.9205	0.2432	H
5.2355	-0.2964	-0.3687	H
4.7997	2.1765	-0.1460	H
-2.8491	0.5176	-0.0670	C
-3.7626	0.3687	1.1639	C
-3.2188	0.5311	2.0960	H
-4.5734	1.0993	1.1154	H
-4.2217	-0.6240	1.2076	H
-3.6710	0.2884	-1.3491	C
-4.1192	-0.7100	-1.3678	H
-4.4882	1.0118	-1.4006	H
-3.0628	0.4030	-2.2478	H
-2.2228	1.9227	-0.0895	C
-1.6626	2.1274	0.8268	H
-1.5621	2.0550	-0.9498	H
-3.0092	2.6778	-0.1624	H
3.2288	-0.7685	-0.1216	N
3.4519	-1.7539	-0.2161	H



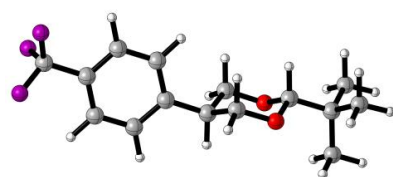
0.9478	-1.6747	-0.1810	C
-1.6892	-0.5894	-0.0172	C
-2.2078	-1.5554	-0.1104	H
0.0503	-1.7345	1.0880	C
0.6346	-1.6954	2.0074	H
-0.5085	-2.6793	1.0731	H
0.0014	-1.5255	-1.3927	C
-0.5799	-2.4460	-1.5171	H
0.5380	-1.3333	-2.3225	H
-0.8753	-0.4155	-1.1863	O
-0.8390	-0.6315	1.1181	O
1.4982	-2.6161	-0.2621	H
1.9497	-0.5564	-0.0883	C
3.2888	-0.7271	0.2512	C
4.1317	0.3764	0.3431	C
3.6636	-1.7257	0.4397	H
2.3107	1.7998	-0.2457	C
3.6392	1.6603	0.0948	C
5.1742	0.2377	0.6069	H
1.8391	2.7499	-0.4601	H
4.2737	2.5345	0.1612	H
-2.7052	0.5537	0.1047	C
-3.5381	0.3175	1.3788	C
-2.9257	0.3652	2.2805	H
-4.3180	1.0782	1.4585	H
-4.0358	-0.6569	1.3589	H
-3.6263	0.5157	-1.1288	C
-4.1534	-0.4399	-1.2079	H
-4.3844	1.2985	-1.0510	H
-3.0732	0.6744	-2.0562	H
-1.9958	1.9170	0.1900	C
-1.3084	1.9625	1.0387	H
-1.4537	2.1493	-0.7326	H
-2.7325	2.7116	0.3276	H
1.5212	0.7086	-0.3248	N
0.5357	0.8056	-0.5949	H



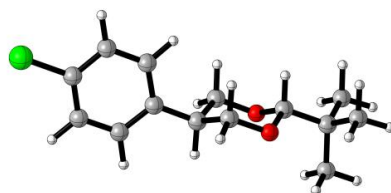
1.2321	1.9970	-0.1104	C
3.4917	0.2605	0.0100	C
4.2431	1.0730	0.0047	H
2.0614	1.7231	1.1639	C
1.4421	1.7595	2.0604	H
2.8502	2.4861	1.2561	H
2.1162	1.6338	-1.3198	C
2.9015	2.3964	-1.4371	H
1.5378	1.5938	-2.2432	H
2.7314	0.3547	-1.1784	O
2.6630	0.4331	1.1418	O
1.0704	3.0813	-0.1510	H
-0.1344	1.3373	-0.0970	C
-1.2701	2.1166	0.1477	C
-0.3192	-0.0362	-0.3053	C
-2.5439	1.5505	0.1874	C
-1.1608	3.1869	0.3073	H
-1.5943	-0.5946	-0.2673	C
0.5372	-0.6686	-0.5008	H
-2.7419	0.1776	-0.0188	C
-3.3927	2.2006	0.3797	H
-1.6868	-1.6651	-0.4363	H
4.2034	-1.1020	0.0772	C
5.0424	-1.1482	1.3669	C
4.4140	-1.0770	2.2560	H
5.6015	-2.0870	1.4183	H
5.7701	-0.3304	1.4023	H
5.1326	-1.2268	-1.1434	C
5.8698	-0.4173	-1.1715	H
5.6836	-2.1708	-1.1020	H
4.5708	-1.2019	-2.0785	H
3.1810	-2.2510	0.0770	C
2.4972	-2.1740	0.9246	H
2.5905	-2.2562	-0.8416	H
3.6985	-3.2127	0.1470	H
-4.4585	-0.6228	0.0265	Si
-5.7710	0.6868	0.3881	C
-6.7664	0.2319	0.4184	H
-5.6121	1.1759	1.3541	H
-5.7984	1.4678	-0.3781	H
-4.8188	-1.4299	-1.6449	C
-4.0736	-2.1900	-1.8990	H
-5.7976	-1.9210	-1.6476	H
-4.8176	-0.6927	-2.4535	H
-4.4983	-1.9441	1.3781	C
-4.3070	-1.5124	2.3651	H
-5.4724	-2.4430	1.4192	H
-3.7436	-2.7192	1.2123	H



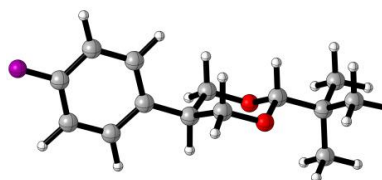
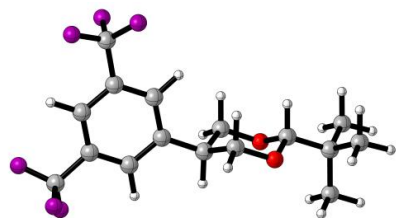
0.7596	0.6091	-0.0000	C
3.4199	-0.3631	0.0000	C
3.1744	-1.4420	0.0001	H
-0.7367	0.3879	-0.0000	C
-1.6118	1.4800	-0.0001	C
-1.2966	-0.8971	0.0000	C
-2.9949	1.3092	-0.0000	C
-1.2086	2.4883	-0.0001	H
-2.6766	-1.0887	0.0000	C
-0.6566	-1.7735	0.0001	H
-3.5165	0.0203	-0.0000	C
-3.6537	2.1692	-0.0001	H
-3.0902	-2.0901	0.0001	H
1.4558	0.0263	-1.2430	C
1.1258	0.5265	-2.1546	H
1.2335	-1.0467	-1.3436	H
1.4558	0.0263	1.2430	C
1.2335	-1.0466	1.3437	H
1.1258	0.5267	2.1546	H
2.8638	0.2150	1.1648	O
2.8638	0.2149	-1.1648	O
0.9548	1.6863	-0.0001	H
4.9467	-0.1729	0.0000	C
5.5224	-0.8505	-1.2563	C
6.6133	-0.7700	-1.2603	H
5.2721	-1.9163	-1.2887	H
5.1441	-0.3887	-2.1696	H
5.5224	-0.8504	1.2563	C
6.6133	-0.7699	1.2603	H
5.1441	-0.3885	2.1696	H
5.2721	-1.9162	1.2889	H
5.3025	1.3236	-0.0000	C
4.9041	1.8255	0.8839	H
6.3894	1.4502	-0.0001	H
4.9041	1.8254	-0.8840	H
-5.4180	-0.2328	0.0000	Br



0.6892	0.6085	0.0063	C
3.3505	-0.3593	-0.0077	C
3.1072	-1.4380	-0.0395	H
-0.8059	0.3852	-0.0071	C
-1.6814	1.4772	0.0193	C
-1.3612	-0.9017	-0.0486	C
-3.0613	1.2996	0.0065	C
-1.2774	2.4844	0.0480	H
-2.7390	-1.0906	-0.0619	C
-0.7172	-1.7743	-0.0734	H
-3.5937	0.0118	-0.0364	C
-3.7190	2.1608	0.0223	H
-3.1471	-2.0940	-0.0998	H
1.3923	0.0608	-1.2497	C
1.0657	0.5855	-2.1487	H
1.1726	-1.0094	-1.3807	H
1.3798	-0.0098	1.2363	C
1.1590	-1.0856	1.3041	H
1.0439	0.4632	2.1602	H
2.7866	0.1849	1.1700	O
2.7983	0.2509	-1.1584	O
0.8834	1.6853	0.0379	H
4.8766	-0.1657	0.0053	C
5.4598	-0.8064	-1.2668	C
6.5505	-0.7239	-1.2628	H
5.2117	-1.8713	-1.3309	H
5.0857	-0.3194	-2.1687	H
5.4475	-0.8775	1.2448	C
6.5381	-0.7947	1.2565	H
5.0639	-0.4426	2.1690	H
5.1995	-1.9444	1.2458	H
5.2291	1.3310	0.0493	C
4.8256	1.8071	0.9451	H
6.3157	1.4595	0.0583	H
4.8342	1.8569	-0.8221	H
-5.0824	-0.1927	0.0021	C
-5.7579	0.8460	-0.5395	F
-5.5419	-0.3294	1.2737	F
-5.4640	-1.3070	-0.6635	F



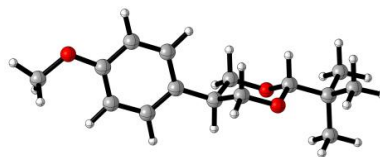
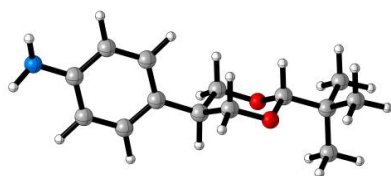
0.0132	0.5766	-0.0000	C
2.6891	-0.3519	0.0000	C
2.4611	-1.4346	0.0001	H
-1.4793	0.3305	-0.0000	C
-2.3727	1.4078	-0.0001	C
-2.0177	-0.9637	0.0000	C
-3.7521	1.2136	-0.0000	C
-1.9861	2.4226	-0.0001	H
-3.3939	-1.1780	0.0000	C
-1.3630	-1.8291	0.0001	H
-4.2523	-0.0835	0.0000	C
-4.4293	2.0595	-0.0001	H
-3.7955	-2.1845	0.0001	H
0.7190	0.0055	-1.2430	C
0.3809	0.5004	-2.1545	H
0.5143	-1.0709	-1.3439	H
0.7190	0.0056	1.2430	C
0.5143	-1.0709	1.3439	H
0.3809	0.5006	2.1545	H
2.1239	0.2171	1.1648	O
2.1239	0.2171	-1.1648	O
0.1905	1.6569	-0.0001	H
-5.9917	-0.3447	0.0000	Cl
4.2127	-0.1373	0.0000	C
4.7992	-0.8056	-1.2563	C
5.8887	-0.7076	-1.2603	H
4.5659	-1.8753	-1.2887	H
4.4135	-0.3499	-2.1695	H
4.7992	-0.8055	1.2563	C
5.8887	-0.7076	1.2603	H
4.4135	-0.3497	2.1696	H
4.5659	-1.8752	1.2889	H
4.5445	1.3647	-0.0000	C
4.1382	1.8602	0.8839	H
5.6293	1.5086	-0.0000	H
4.1382	1.8601	-0.8840	H



*very tight convergence

-1.0306	-0.6404	0.0152	C
-3.7410	0.1754	-0.0083	C
-3.5567	1.2655	-0.0351	H
0.4485	-0.3287	0.0091	C
1.3867	-1.3645	0.0364	C
0.9225	0.9882	-0.0238	C
2.7547	-1.0949	0.0315	C
1.0452	-2.3934	0.0660	H
2.2905	1.2551	-0.0309	C
0.2265	1.8184	-0.0497	H
3.2184	0.2170	-0.0029	C
-1.7580	-0.1292	-1.2436	C
-1.3974	-0.6318	-2.1423	H
-1.5986	0.9522	-1.3707	H
-1.7611	-0.0679	1.2454	C
-1.6020	1.0186	1.3193	H
-1.4028	-0.5254	2.1688	H
-3.1522	-0.3424	1.1699	O
-3.1492	-0.4000	-1.1580	O
-1.1604	-1.7266	0.0418	H
-5.2537	-0.1020	-0.0034	C
-5.8647	0.5105	-1.2765	C
-6.9492	0.3687	-1.2776	H
-5.6748	1.5875	-1.3360	H
-5.4609	0.0475	-2.1782	H
-5.8680	0.5736	1.2357	C
-6.9525	0.4316	1.2413	H
-5.4664	0.1569	2.1606	H
-5.6786	1.6524	1.2413	H
-5.5242	-1.6159	0.0342	C
-5.1004	-2.0727	0.9307	H
-6.6022	-1.8028	0.0372	H
-5.0976	-2.1170	-0.8369	H
4.2799	0.4265	-0.0080	H
3.7328	-2.2412	0.0064	C
4.9518	-1.8840	0.4608	F
3.3110	-3.2813	0.7598	F
2.7628	2.6861	-0.0106	C
3.9068	-2.7192	-1.2509	F
4.0105	2.8207	-0.5050	F
1.9545	3.4955	-0.7319	F
2.7839	3.1856	1.2504	F

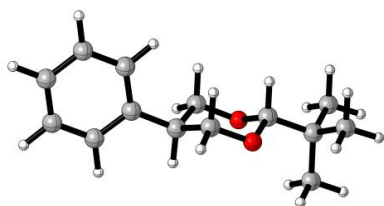
-0.4000	0.5443	-0.0000	C
2.2908	-0.3403	0.0000	C
2.0798	-1.4265	0.0001	H
-1.8890	0.2739	-0.0000	C
-2.7989	1.3381	-0.0001	C
-2.4051	-1.0300	0.0000	C
-4.1756	1.1225	-0.0000	C
-2.4268	2.3581	-0.0001	H
-3.7778	-1.2678	0.0000	C
-1.7346	-1.8831	0.0001	H
-4.6393	-0.1825	0.0000	C
-4.8794	1.9469	-0.0001	H
-4.1785	-2.2750	0.0001	H
0.3152	-0.0142	-1.2429	C
-0.0308	0.4757	-2.1542	H
0.1280	-1.0938	-1.3446	H
0.3152	-0.0141	1.2429	C
0.1280	-1.0937	1.3447	H
-0.0308	0.4759	2.1542	H
1.7169	0.2197	1.1648	O
1.7169	0.2196	-1.1649	O
-0.2409	1.6275	-0.0001	H
3.8109	-0.1022	0.0000	C
4.4077	-0.7614	-1.2563	C
5.4956	-0.6467	-1.2603	H
4.1909	-1.8346	-1.2887	H
4.0150	-0.3117	-2.1695	H
4.4077	-0.7613	1.2563	C
5.4956	-0.6466	1.2603	H
4.0150	-0.3115	2.1695	H
4.1909	-1.8345	1.2888	H
4.1197	1.4047	-0.0000	C
3.7057	1.8939	0.8838	H
5.2022	1.5653	-0.0000	H
3.7057	1.8938	-0.8840	H
-5.9768	-0.4059	0.0000	F



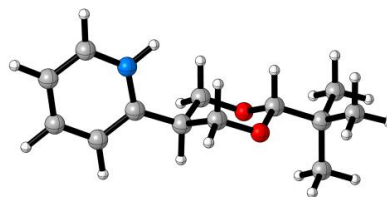
*very tight, very fine convergence

-0.3831	0.5509	-0.0063	C
2.3074	-0.3405	0.0039	C
2.0927	-1.4261	0.0188	H
-1.8721	0.2814	-0.0012	C
-2.7888	1.3390	-0.0130	C
-2.3990	-1.0175	0.0153	C
-4.1621	1.1213	-0.0089	C
-2.4212	2.3614	-0.0264	H
-3.7698	-1.2496	0.0199	C
-1.7338	-1.8757	0.0248	H
-4.6781	-0.1816	0.0066	C
-4.8418	1.9692	-0.0119	H
-4.1418	-2.2705	0.0398	H
0.3313	-0.0235	-1.2412	C
-0.0131	0.4568	-2.1582	H
0.1408	-1.1036	-1.3305	H
0.3330	0.0102	1.2427	C
0.1428	-1.0671	1.3615	H
-0.0101	0.5150	2.1468	H
1.7379	0.2367	1.1614	O
1.7362	0.2049	-1.1684	O
-0.2241	1.6345	-0.0211	H
3.8290	-0.1089	-0.0004	C
4.4228	-0.7873	-1.2476	C
5.5111	-0.6767	-1.2543	H
4.2017	-1.8601	-1.2650	H
4.0303	-0.3490	-2.1665	H
4.4243	-0.7526	1.2645	C
5.5127	-0.6421	1.2666	H
4.0332	-0.2889	2.1713	H
4.2030	-1.8244	1.3120	H
4.1436	1.3967	-0.0213	C
3.7310	1.8991	0.8558	H
5.2267	1.5536	-0.0238	H
3.7304	1.8748	-0.9116	H
-6.0558	-0.4097	0.0704	N
-6.6379	0.3376	-0.2789	H
-6.3647	-1.3110	-0.2634	H

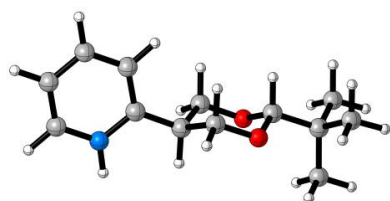
0.0162	0.5135	0.0000	C
2.7229	-0.3249	0.0000	C
2.5294	-1.4145	0.0000	H
-1.4671	0.2142	0.0000	C
-2.4010	1.2507	0.0000	C
-1.9643	-1.1003	0.0000	C
-3.7769	1.0099	0.0000	C
-2.0539	2.2802	0.0000	H
-3.3265	-1.3600	0.0000	C
-1.2795	-1.9426	0.0000	H
-4.2464	-0.3047	0.0000	C
-4.4599	1.8502	0.0000	H
-3.7025	-2.3773	0.0000	H
0.7419	-0.0306	-1.2424	C
0.3883	0.4550	-2.1531	H
0.5730	-1.1129	-1.3463	H
0.7419	-0.0306	1.2424	C
0.5730	-1.1129	1.3463	H
0.3883	0.4550	2.1531	H
2.1413	0.2255	1.1649	O
2.1413	0.2255	-1.1649	O
0.1541	1.5999	0.0000	H
4.2395	-0.0636	0.0000	C
4.8467	-0.7131	-1.2562	C
5.9327	-0.5814	-1.2605	H
4.6464	-1.7895	-1.2886	H
4.4465	-0.2697	-2.1692	H
4.8467	-0.7131	1.2562	C
5.9327	-0.5814	1.2605	H
4.4465	-0.2697	2.1692	H
4.6464	-1.7895	1.2886	H
4.5250	1.4480	0.0000	C
4.1029	1.9304	0.8838	H
5.6049	1.6256	0.0000	H
4.1029	1.9304	-0.8838	H
-5.5640	-0.6613	0.0000	O
-6.5448	0.3644	0.0000	C
-7.5073	-0.1441	0.0000	H
-6.4679	0.9921	0.8941	H
-6.4679	0.9921	-0.8941	H



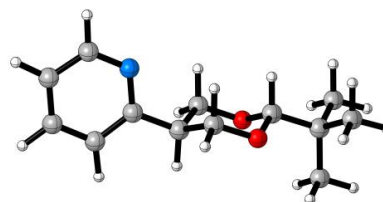
0.8111	0.5121	-0.0012	C
-1.8950	-0.3259	0.0007	C
-1.6980	-1.4147	0.0033	H
2.2935	0.2053	-0.0005	C
3.2283	1.2477	-0.0023	C
2.7755	-1.1115	0.0020	C
4.5979	0.9891	-0.0017	C
2.8775	2.2760	-0.0042	H
4.1439	-1.3745	0.0026	C
2.0809	-1.9457	0.0035	H
5.0611	-0.3249	0.0007	C
5.3020	1.8152	-0.0032	H
4.4937	-2.4022	0.0045	H
0.0843	-0.0273	1.2436	C
0.4377	0.4621	2.1522	H
0.2528	-1.1090	1.3519	H
0.0843	-0.0330	-1.2435	C
0.2530	-1.1151	-1.3471	H
0.4377	0.4524	-2.1544	H
-1.3141	0.2240	-1.1650	O
-1.3141	0.2295	1.1638	O
0.6785	1.5989	-0.0037	H
-3.4121	-0.0689	0.0002	C
6.1268	-0.5297	0.0012	H
-4.0181	-0.7230	-1.2544	C
-5.1039	-0.5895	-1.2604	H
-3.6164	-0.2838	-2.1687	H
-3.8195	-1.7998	-1.2821	H
-4.0178	-0.7170	1.2580	C
-3.6158	-0.2734	2.1701	H
-5.1036	-0.5836	1.2637	H
-3.8192	-1.7937	1.2907	H
-3.7021	1.4418	-0.0034	C
-3.2822	1.9240	-0.8883	H
-4.7826	1.6153	-0.0037	H
-3.2820	1.9282	0.8792	H



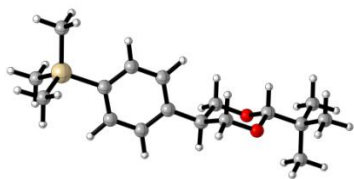
0.7911	0.5292	-0.0000	C
-1.9086	-0.3348	0.0000	C
-1.7120	-1.4216	0.0000	H
2.2619	0.2769	-0.0000	C
3.2274	1.2827	-0.0000	C
4.0245	-1.3551	0.0000	C
4.5803	0.9634	-0.0000	C
2.9024	2.3156	-0.0001	H
4.9895	-0.3747	0.0000	C
4.2400	-2.4156	0.0001	H
5.3207	1.7557	-0.0000	H
0.0662	-0.0394	1.2534	C
0.4239	0.4369	2.1673	H
0.2409	-1.1262	1.3416	H
0.0662	-0.0395	-1.2534	C
0.2409	-1.1263	-1.3416	H
0.4239	0.4368	-2.1673	H
-1.3080	0.2224	-1.1622	O
-1.3080	0.2225	1.1622	O
0.6387	1.6106	-0.0000	H
-3.4185	-0.0629	0.0000	C
6.0362	-0.6499	0.0000	H
-4.0237	-0.7139	-1.2576	C
-5.1079	-0.5802	-1.2580	H
-3.6311	-0.2697	-2.1737	H
-3.8292	-1.7911	-1.2902	H
-4.0237	-0.7138	1.2577	C
-3.6311	-0.2696	2.1737	H
-5.1079	-0.5802	1.2581	H
-3.8292	-1.7910	1.2903	H
-3.6978	1.4502	-0.0000	C
-3.2822	1.9354	-0.8855	H
-4.7764	1.6257	-0.0000	H
-3.2822	1.9354	0.8854	H
2.7156	-1.0065	0.0000	N
2.0298	-1.7542	0.0000	H



0.7858	0.4996	-0.0010	C
-1.9234	-0.3287	0.0006	C
-1.7302	-1.4182	0.0028	H
2.2670	0.1875	-0.0004	C
2.7443	-1.1310	0.0016	C
4.5742	0.9630	-0.0013	C
4.1118	-1.3990	0.0021	C
2.0467	-1.9628	0.0028	H
5.0327	-0.3527	0.0007	C
5.2814	1.7866	-0.0024	H
4.4578	-2.4279	0.0037	H
0.0570	-0.0377	1.2436	C
0.4122	0.4501	2.1524	H
0.2216	-1.1201	1.3515	H
0.0570	-0.0424	-1.2435	C
0.2218	-1.1251	-1.3475	H
0.4122	0.4421	-2.1542	H
-1.3404	0.2195	-1.1649	O
-1.3404	0.2241	1.1639	O
0.6571	1.5869	-0.0030	H
-3.4395	-0.0662	0.0002	C
6.0977	-0.5613	0.0011	H
-4.0478	-0.7177	-1.2546	C
-5.1331	-0.5803	-1.2606	H
-3.6445	-0.2796	-2.1688	H
-3.8531	-1.7952	-1.2827	H
-4.0475	-0.7127	1.2577	C
-3.6440	-0.2708	2.1700	H
-5.1328	-0.5753	1.2635	H
-3.8528	-1.7900	1.2900	H
-3.7241	1.4454	-0.0028	C
-3.3024	1.9265	-0.8876	H
-4.8039	1.6229	-0.0031	H
-3.3023	1.9300	0.8799	H
3.2056	1.2265	-0.0018	N
2.9124	2.1826	-0.0042	H

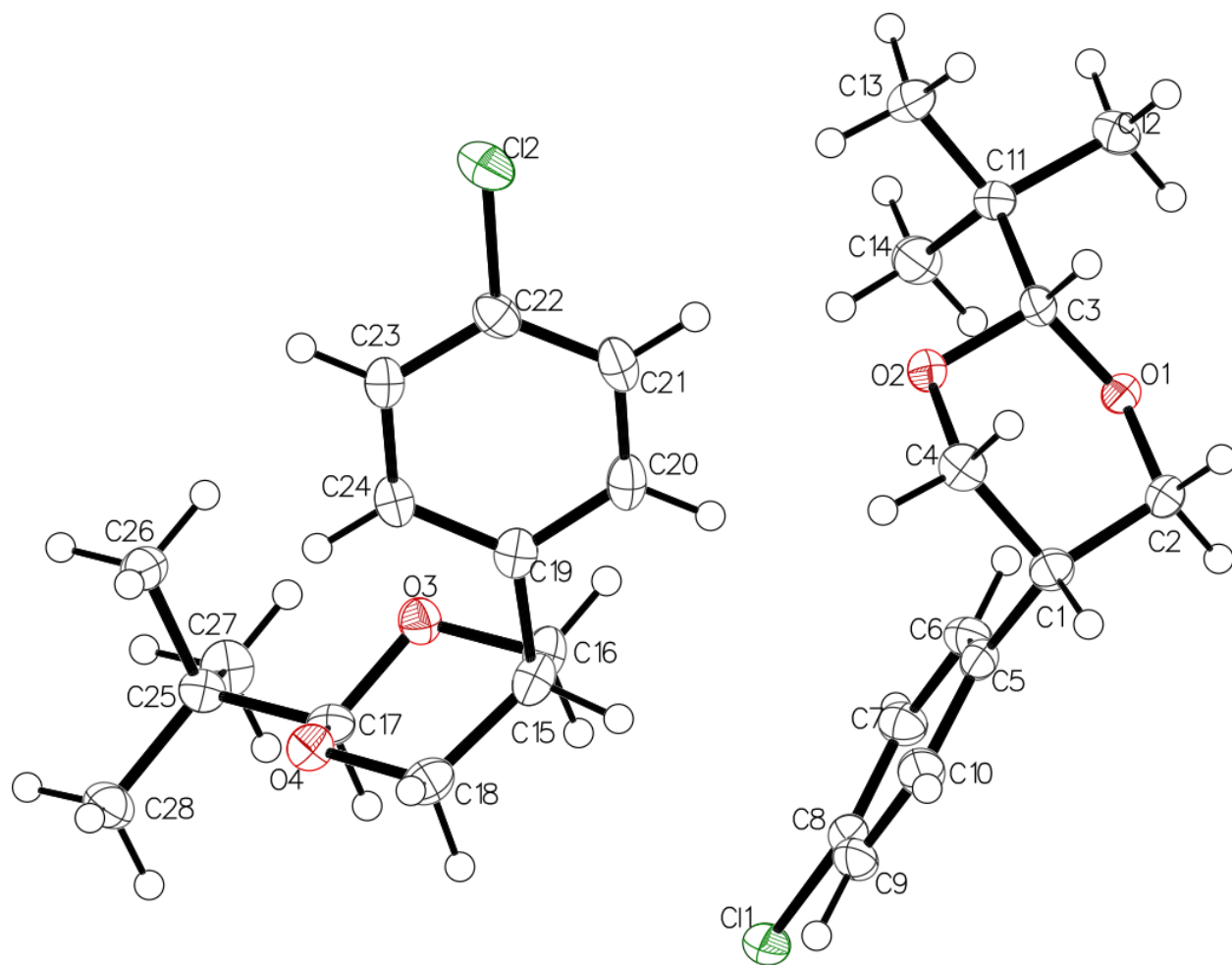


0.8270	0.5597	-0.0000	C
-1.8654	-0.3224	0.0000	C
-1.6539	-1.4075	0.0000	H
2.3020	0.2342	-0.0000	C
3.2688	1.2466	-0.0000	C
3.9337	-1.3870	0.0000	C
4.6162	0.9008	-0.0000	C
2.9635	2.2877	-0.0000	H
4.9620	-0.4473	0.0000	C
4.1600	-2.4506	0.0000	H
5.3818	1.6703	-0.0000	H
0.1102	-0.0008	1.2423	C
0.4545	0.4870	2.1559	H
0.3050	-1.0777	1.3269	H
0.1102	-0.0009	-1.2423	C
0.3050	-1.0777	-1.3268	H
0.4545	0.4869	-2.1559	H
-1.2913	0.2395	-1.1637	O
-1.2913	0.2396	1.1637	O
0.6988	1.6467	-0.0000	H
-3.3851	-0.0823	0.0000	C
5.9983	-0.7667	0.0000	H
-3.9837	-0.7401	-1.2562	C
-5.0708	-0.6178	-1.2627	H
-3.5857	-0.2948	-2.1693	H
-3.7735	-1.8145	-1.2861	H
-3.9837	-0.7400	1.2562	C
-3.5857	-0.2947	2.1693	H
-5.0708	-0.6178	1.2627	H
-3.7735	-1.8145	1.2862	H
-3.6926	1.4249	-0.0000	C
-3.2779	1.9138	-0.8838	H
-4.7750	1.5862	-0.0000	H
-3.2779	1.9138	0.8837	H
2.6380	-1.0662	0.0000	N



1.0890	-0.6199	-0.0000	C
3.7453	0.3649	0.0000	C
3.4946	1.4427	0.0000	H
-0.4084	-0.4043	-0.0000	C
-1.2804	-1.4997	-0.0000	C
-0.9755	0.8760	0.0000	C
-2.6612	-1.3218	-0.0000	C
-0.8706	-2.5062	-0.0000	H
-2.3590	1.0493	0.0000	C
-0.3383	1.7555	0.0000	H
-3.2407	-0.0422	0.0000	C
-3.2933	-2.2068	-0.0000	H
-2.7506	2.0625	0.0000	H
1.7827	-0.0343	1.2425	C
1.4556	-0.5369	2.1539	H
1.5552	1.0373	1.3437	H
1.7827	-0.0343	-1.2425	C
1.5552	1.0373	-1.3437	H
1.4556	-0.5369	-2.1539	H
3.1930	-0.2155	-1.1649	O
3.1930	-0.2155	1.1649	O
1.2887	-1.6965	-0.0000	H
5.2733	0.1827	0.0000	C
5.8459	0.8630	1.2562	C
6.9372	0.7879	1.2605	H
5.5901	1.9276	1.2887	H
5.4694	0.3994	2.1693	H
5.8459	0.8630	-1.2562	C
6.9372	0.7879	-1.2605	H
5.4694	0.3994	-2.1693	H
5.5901	1.9276	-1.2887	H
5.6368	-1.3119	-0.0000	C
5.2404	-1.8156	-0.8838	H
6.7244	-1.4334	-0.0000	H
5.2404	-1.8156	0.8838	H
-5.1254	0.1705	0.0000	Si
-5.8457	-0.6516	1.5420	C
-6.9369	-0.5631	1.5665	H
-5.6064	-1.7186	1.5855	H
-5.4577	-0.1951	2.4576	H
-5.5638	2.0072	0.0000	C
-5.1778	2.5252	-0.8833	H
-6.6506	2.1397	0.0000	H
-5.1778	2.5252	0.8833	H
-5.8457	-0.6516	-1.5420	C
-5.6064	-1.7186	-1.5855	H
-6.9369	-0.5630	-1.5665	H
-5.4577	-0.1951	-2.4576	H

X-Ray Crystallographic Data



The full numbering scheme of **3**. All atoms shown are depicted with 50% thermal contours. The hydrogen atoms are shown as arbitrary spheres.

Crystal data and structure refinement for **3**.

Identification code	mini-15050	
Empirical formula	C ₁₄ H ₁₉ ClO ₂	
Formula weight	254.74	
Temperature	93(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group	P2 ₁ /n	
Unit cell dimensions	a = 11.2073(8) Å	α = 90°.
	b = 11.4382(8) Å	β = 95.208(3)°.
	c = 20.9983(15) Å	γ = 90°.
Volume	2680.7(3) Å ³	
Z	8	
Density (calculated)	1.262 Mg/m ³	
Absorption coefficient	0.273 mm ⁻¹	
F(000)	1088	
Crystal size	0.220 x 0.210 x 0.080 mm ³	
Θ range for data collection	1.989 to 27.627°.	
Index ranges	-14 ≤ h ≤ 14, -14 ≤ k ≤ 14, -27 ≤ l ≤ 27	
Reflections collected	45954	
Independent reflections	6225 [R(int) = 0.0414]	
Completeness to θ = 25.242°	99.8 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.978 and 0.877	
Refinement method	Full-matrix least-squares on F ²	
Data / restraints / parameters	6225 / 0 / 313	
Goodness-of-fit on F ²	1.051	
Final R indices [I>2σ(I)]	R1 = 0.0374, wR2 = 0.0916	
R indices (all data)	R1 = 0.0523, wR2 = 0.1016	
Largest diff. peak and hole	0.342 and -0.291 e.Å ⁻³	

Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement parameters ($\text{\AA}^2 \times 10^3$)

for **3**. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)
Cl(1)	7681(1)	3557(1)	5486(1)	26(1)
O(1)	10976(1)	3670(1)	2803(1)	19(1)
O(2)	9109(1)	4298(1)	2380(1)	19(1)
C(1)	10106(1)	5403(1)	3256(1)	21(1)
C(2)	11237(1)	4763(1)	3112(1)	22(1)
C(3)	10202(1)	3796(1)	2243(1)	18(1)
C(4)	9286(1)	5444(1)	2636(1)	22(1)
C(5)	9495(1)	4901(1)	3805(1)	19(1)
C(6)	9542(1)	3729(1)	3967(1)	22(1)
C(7)	8986(1)	3305(1)	4482(1)	23(1)
C(8)	8377(1)	4075(1)	4837(1)	22(1)
C(9)	8298(1)	5243(1)	4688(1)	25(1)
C(10)	8860(1)	5645(1)	4172(1)	25(1)
C(11)	9962(1)	2594(1)	1949(1)	21(1)
C(12)	11154(2)	2057(2)	1815(1)	29(1)
C(13)	9180(2)	2740(2)	1322(1)	30(1)
C(14)	9336(2)	1812(1)	2402(1)	27(1)
Cl(2)	5118(1)	3817(1)	1081(1)	31(1)
O(3)	4770(1)	1469(1)	4029(1)	22(1)
O(4)	3552(1)	3039(1)	4228(1)	22(1)
C(15)	5572(1)	3416(1)	3942(1)	25(1)
C(16)	5831(1)	2147(1)	4128(1)	26(1)
C(17)	3889(1)	1893(1)	4407(1)	20(1)
C(18)	4541(2)	3823(1)	4303(1)	25(1)
C(19)	5396(1)	3545(1)	3226(1)	21(1)
C(20)	6407(1)	3684(1)	2897(1)	25(1)
C(21)	6326(1)	3773(1)	2243(1)	25(1)
C(22)	5217(1)	3716(1)	1908(1)	22(1)
C(23)	4194(1)	3578(1)	2214(1)	22(1)
C(24)	4289(1)	3489(1)	2874(1)	22(1)
C(25)	2803(1)	1104(1)	4326(1)	21(1)
C(26)	2274(1)	1112(1)	3631(1)	23(1)
C(27)	3190(2)	-127(1)	4532(1)	29(1)
C(28)	1878(2)	1542(2)	4756(1)	28(1)

Bond lengths [Å] and angles [°] for **3**.

Cl(1)-C(8)	1.7356(15)
O(1)-C(3)	1.4024(17)
O(1)-C(2)	1.4269(17)
O(2)-C(3)	1.4064(17)
O(2)-C(4)	1.4243(18)
C(1)-C(5)	1.506(2)
C(1)-C(2)	1.518(2)
C(1)-C(4)	1.523(2)
C(1)-H(1)	1.0000
C(2)-H(2A)	0.9900
C(2)-H(2B)	0.9900
C(3)-C(11)	1.521(2)
C(3)-H(3)	1.0000
C(4)-H(4A)	0.9900
C(4)-H(4B)	0.9900
C(5)-C(6)	1.383(2)
C(5)-C(10)	1.387(2)
C(6)-C(7)	1.385(2)
C(6)-H(6)	0.9500
C(7)-C(8)	1.374(2)
C(7)-H(7)	0.9500
C(8)-C(9)	1.373(2)
C(9)-C(10)	1.380(2)
C(9)-H(9)	0.9500
C(10)-H(10)	0.9500
C(11)-C(12)	1.521(2)
C(11)-C(14)	1.522(2)
C(11)-C(13)	1.523(2)
C(12)-H(12A)	0.9800
C(12)-H(12B)	0.9800
C(12)-H(12C)	0.9800
C(13)-H(13A)	0.9800
C(13)-H(13B)	0.9800
C(13)-H(13C)	0.9800
C(14)-H(14A)	0.9800
C(14)-H(14B)	0.9800
C(14)-H(14C)	0.9800
Cl(2)-C(22)	1.7351(16)
O(3)-C(17)	1.4079(18)
O(3)-C(16)	1.4192(18)
O(4)-C(17)	1.4064(17)
O(4)-C(18)	1.4232(19)
C(15)-C(19)	1.506(2)
C(15)-C(18)	1.511(2)
C(15)-C(16)	1.524(2)
C(15)-H(15)	1.0000
C(16)-H(16A)	0.9900
C(16)-H(16B)	0.9900
C(17)-C(25)	1.512(2)
C(17)-H(17)	1.0000
C(18)-H(18A)	0.9900
C(18)-H(18B)	0.9900
C(19)-C(24)	1.387(2)
C(19)-C(20)	1.388(2)

C(20)-C(21)	1.372(2)
C(20)-H(20)	0.9500
C(21)-C(22)	1.373(2)
C(21)-H(21)	0.9500
C(22)-C(23)	1.373(2)
C(23)-C(24)	1.384(2)
C(23)-H(23)	0.9500
C(24)-H(24)	0.9500
C(25)-C(28)	1.519(2)
C(25)-C(27)	1.524(2)
C(25)-C(26)	1.525(2)
C(26)-H(26A)	0.9800
C(26)-H(26B)	0.9800
C(26)-H(26C)	0.9800
C(27)-H(27A)	0.9800
C(27)-H(27B)	0.9800
C(27)-H(27C)	0.9800
C(28)-H(28A)	0.9800
C(28)-H(28B)	0.9800
C(28)-H(28C)	0.9800
C(3)-O(1)-C(2)	112.18(11)
C(3)-O(2)-C(4)	111.02(11)
C(5)-C(1)-C(2)	114.49(13)
C(5)-C(1)-C(4)	112.63(12)
C(2)-C(1)-C(4)	107.15(12)
C(5)-C(1)-H(1)	107.4
C(2)-C(1)-H(1)	107.4
C(4)-C(1)-H(1)	107.4
O(1)-C(2)-C(1)	111.82(12)
O(1)-C(2)-H(2A)	109.3
C(1)-C(2)-H(2A)	109.3
O(1)-C(2)-H(2B)	109.3
C(1)-C(2)-H(2B)	109.3
H(2A)-C(2)-H(2B)	107.9
O(1)-C(3)-O(2)	110.78(11)
O(1)-C(3)-C(11)	108.74(12)
O(2)-C(3)-C(11)	109.06(11)
O(1)-C(3)-H(3)	109.4
O(2)-C(3)-H(3)	109.4
C(11)-C(3)-H(3)	109.4
O(2)-C(4)-C(1)	110.31(12)
O(2)-C(4)-H(4A)	109.6
C(1)-C(4)-H(4A)	109.6
O(2)-C(4)-H(4B)	109.6
C(1)-C(4)-H(4B)	109.6
H(4A)-C(4)-H(4B)	108.1
C(6)-C(5)-C(10)	117.88(14)
C(6)-C(5)-C(1)	123.19(13)
C(10)-C(5)-C(1)	118.92(13)
C(5)-C(6)-C(7)	121.46(14)
C(5)-C(6)-H(6)	119.3
C(7)-C(6)-H(6)	119.3
C(8)-C(7)-C(6)	118.70(15)
C(8)-C(7)-H(7)	120.7
C(6)-C(7)-H(7)	120.7

C(9)-C(8)-C(7)	121.62(14)
C(9)-C(8)-Cl(1)	119.19(12)
C(7)-C(8)-Cl(1)	119.19(12)
C(8)-C(9)-C(10)	118.63(14)
C(8)-C(9)-H(9)	120.7
C(10)-C(9)-H(9)	120.7
C(9)-C(10)-C(5)	121.70(15)
C(9)-C(10)-H(10)	119.2
C(5)-C(10)-H(10)	119.2
C(12)-C(11)-C(3)	108.31(12)
C(12)-C(11)-C(14)	109.90(14)
C(3)-C(11)-C(14)	110.61(12)
C(12)-C(11)-C(13)	109.28(13)
C(3)-C(11)-C(13)	108.62(13)
C(14)-C(11)-C(13)	110.08(13)
C(11)-C(12)-H(12A)	109.5
C(11)-C(12)-H(12B)	109.5
H(12A)-C(12)-H(12B)	109.5
C(11)-C(12)-H(12C)	109.5
H(12A)-C(12)-H(12C)	109.5
H(12B)-C(12)-H(12C)	109.5
C(11)-C(13)-H(13A)	109.5
C(11)-C(13)-H(13B)	109.5
H(13A)-C(13)-H(13B)	109.5
C(11)-C(13)-H(13C)	109.5
H(13A)-C(13)-H(13C)	109.5
H(13B)-C(13)-H(13C)	109.5
C(11)-C(14)-H(14A)	109.5
C(11)-C(14)-H(14B)	109.5
H(14A)-C(14)-H(14B)	109.5
C(11)-C(14)-H(14C)	109.5
H(14A)-C(14)-H(14C)	109.5
H(14B)-C(14)-H(14C)	109.5
C(17)-O(3)-C(16)	110.48(12)
C(17)-O(4)-C(18)	111.72(12)
C(19)-C(15)-C(18)	115.72(13)
C(19)-C(15)-C(16)	110.70(13)
C(18)-C(15)-C(16)	107.56(13)
C(19)-C(15)-H(15)	107.5
C(18)-C(15)-H(15)	107.5
C(16)-C(15)-H(15)	107.5
O(3)-C(16)-C(15)	110.21(12)
O(3)-C(16)-H(16A)	109.6
C(15)-C(16)-H(16A)	109.6
O(3)-C(16)-H(16B)	109.6
C(15)-C(16)-H(16B)	109.6
H(16A)-C(16)-H(16B)	108.1
O(4)-C(17)-O(3)	110.86(12)
O(4)-C(17)-C(25)	109.40(12)
O(3)-C(17)-C(25)	109.27(12)
O(4)-C(17)-H(17)	109.1
O(3)-C(17)-H(17)	109.1
C(25)-C(17)-H(17)	109.1
O(4)-C(18)-C(15)	111.94(13)
O(4)-C(18)-H(18A)	109.2
C(15)-C(18)-H(18A)	109.2

O(4)-C(18)-H(18B)	109.2
C(15)-C(18)-H(18B)	109.2
H(18A)-C(18)-H(18B)	107.9
C(24)-C(19)-C(20)	118.13(15)
C(24)-C(19)-C(15)	123.82(14)
C(20)-C(19)-C(15)	118.01(14)
C(21)-C(20)-C(19)	121.58(15)
C(21)-C(20)-H(20)	119.2
C(19)-C(20)-H(20)	119.2
C(20)-C(21)-C(22)	118.93(14)
C(20)-C(21)-H(21)	120.5
C(22)-C(21)-H(21)	120.5
C(23)-C(22)-C(21)	121.40(15)
C(23)-C(22)-Cl(2)	119.76(13)
C(21)-C(22)-Cl(2)	118.85(12)
C(22)-C(23)-C(24)	119.06(14)
C(22)-C(23)-H(23)	120.5
C(24)-C(23)-H(23)	120.5
C(23)-C(24)-C(19)	120.91(14)
C(23)-C(24)-H(24)	119.5
C(19)-C(24)-H(24)	119.5
C(17)-C(25)-C(28)	108.79(13)
C(17)-C(25)-C(27)	108.27(13)
C(28)-C(25)-C(27)	109.20(13)
C(17)-C(25)-C(26)	110.01(12)
C(28)-C(25)-C(26)	109.88(13)
C(27)-C(25)-C(26)	110.65(13)
C(25)-C(26)-H(26A)	109.5
C(25)-C(26)-H(26B)	109.5
H(26A)-C(26)-H(26B)	109.5
C(25)-C(26)-H(26C)	109.5
H(26A)-C(26)-H(26C)	109.5
H(26B)-C(26)-H(26C)	109.5
C(25)-C(27)-H(27A)	109.5
C(25)-C(27)-H(27B)	109.5
H(27A)-C(27)-H(27B)	109.5
C(25)-C(27)-H(27C)	109.5
H(27A)-C(27)-H(27C)	109.5
H(27B)-C(27)-H(27C)	109.5
C(25)-C(28)-H(28A)	109.5
C(25)-C(28)-H(28B)	109.5
H(28A)-C(28)-H(28B)	109.5
C(25)-C(28)-H(28C)	109.5
H(28A)-C(28)-H(28C)	109.5
H(28B)-C(28)-H(28C)	109.5

Symmetry transformations used to generate equivalent atoms:

Anisotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for **3**. The anisotropic displacement factor exponent takes the form: $-2\pi^2 [h^2 a^{*2} U^{11} + \dots + 2 h k a^* b^* U^{12}]$

	U ¹¹	U ²²	U ³³	U ²³	U ¹³	U ¹²
Cl(1)	26(1)	34(1)	20(1)	-3(1)	5(1)	-4(1)
O(1)	17(1)	21(1)	18(1)	-3(1)	0(1)	0(1)
O(2)	16(1)	21(1)	20(1)	-1(1)	2(1)	1(1)
C(1)	22(1)	18(1)	23(1)	-3(1)	3(1)	-1(1)
C(2)	18(1)	24(1)	23(1)	-5(1)	1(1)	-4(1)
C(3)	15(1)	23(1)	18(1)	0(1)	3(1)	-1(1)
C(4)	24(1)	19(1)	24(1)	2(1)	2(1)	2(1)
C(5)	16(1)	20(1)	20(1)	-3(1)	-1(1)	-2(1)
C(6)	25(1)	23(1)	19(1)	-2(1)	3(1)	5(1)
C(7)	26(1)	23(1)	21(1)	1(1)	3(1)	3(1)
C(8)	18(1)	30(1)	18(1)	-3(1)	1(1)	-2(1)
C(9)	23(1)	24(1)	29(1)	-10(1)	8(1)	-3(1)
C(10)	25(1)	18(1)	32(1)	-5(1)	5(1)	-1(1)
C(11)	20(1)	25(1)	20(1)	-5(1)	4(1)	-2(1)
C(12)	24(1)	32(1)	31(1)	-11(1)	7(1)	1(1)
C(13)	27(1)	42(1)	21(1)	-8(1)	0(1)	-7(1)
C(14)	29(1)	22(1)	30(1)	-4(1)	7(1)	-4(1)
Cl(2)	34(1)	34(1)	26(1)	1(1)	10(1)	7(1)
O(3)	20(1)	21(1)	25(1)	0(1)	2(1)	1(1)
O(4)	24(1)	18(1)	24(1)	1(1)	1(1)	0(1)
C(15)	21(1)	24(1)	27(1)	2(1)	-4(1)	-4(1)
C(16)	21(1)	26(1)	29(1)	4(1)	-4(1)	-1(1)
C(17)	25(1)	19(1)	18(1)	0(1)	1(1)	2(1)
C(18)	30(1)	20(1)	25(1)	-2(1)	-1(1)	-3(1)
C(19)	21(1)	16(1)	27(1)	2(1)	0(1)	0(1)
C(20)	16(1)	21(1)	36(1)	1(1)	0(1)	1(1)
C(21)	18(1)	23(1)	36(1)	0(1)	8(1)	1(1)
C(22)	24(1)	18(1)	25(1)	0(1)	7(1)	2(1)
C(23)	17(1)	22(1)	27(1)	2(1)	1(1)	0(1)
C(24)	17(1)	22(1)	27(1)	3(1)	4(1)	1(1)
C(25)	24(1)	18(1)	20(1)	2(1)	3(1)	0(1)
C(26)	25(1)	24(1)	21(1)	-1(1)	1(1)	-2(1)
C(27)	31(1)	21(1)	34(1)	5(1)	3(1)	1(1)
C(28)	28(1)	30(1)	25(1)	-2(1)	9(1)	-1(1)

Hydrogen coordinates ($\times 10^4$) and isotropic displacement parameters ($\text{\AA}^2 \times 10^{-3}$)
for **3**.

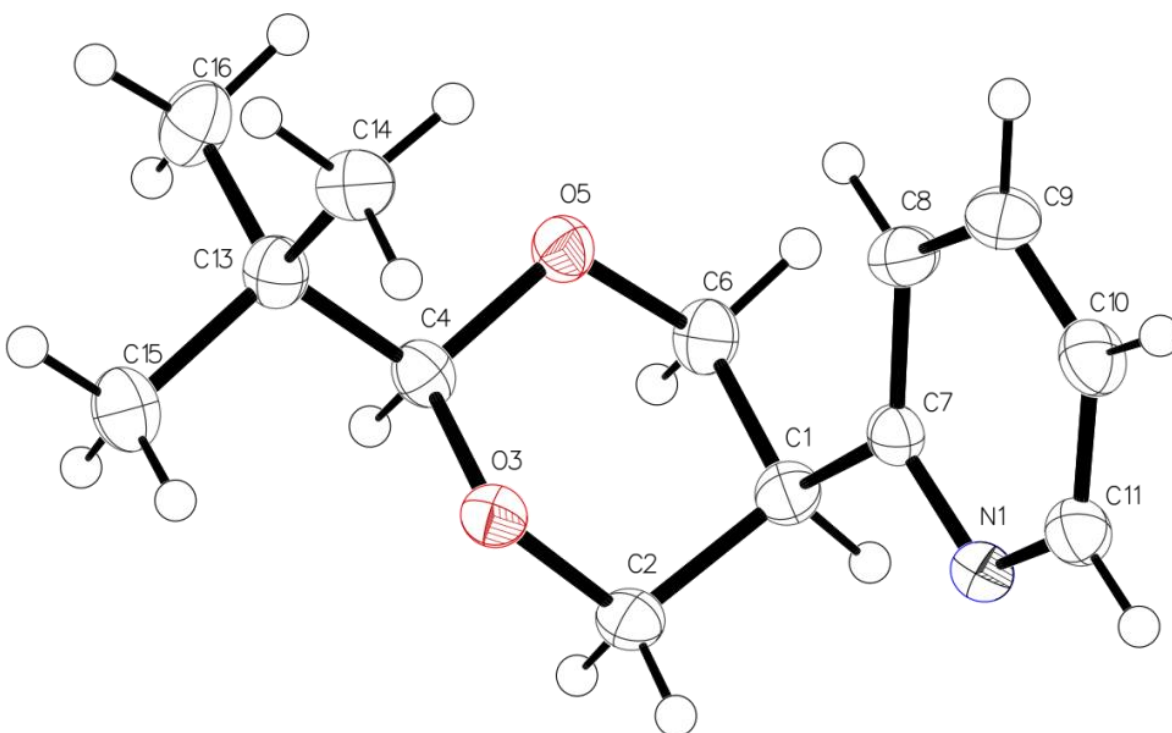
	x	y	z	U(eq)
H(1)	10337	6226	3371	25
H(2A)	11697	5258	2834	26
H(2B)	11744	4626	3516	26
H(3)	10589	4304	1934	22
H(4A)	8504	5786	2720	27
H(4B)	9648	5948	2322	27
H(6)	9965	3203	3719	27
H(7)	9024	2498	4589	28
H(9)	7866	5763	4934	30
H(10)	8809	6452	4065	30
H(12A)	11551	2563	1522	43
H(12B)	11016	1285	1619	43
H(12C)	11665	1975	2217	43
H(13A)	8394	3044	1409	45
H(13B)	9081	1981	1107	45
H(13C)	9564	3289	1045	45
H(14A)	9858	1699	2797	40
H(14B)	9162	1052	2198	40
H(14C)	8586	2180	2501	40
H(15)	6291	3887	4098	29
H(16A)	6448	1828	3867	31
H(16B)	6145	2106	4584	31
H(17)	4217	1889	4866	24
H(18A)	4816	3893	4763	30
H(18B)	4279	4606	4146	30
H(20)	7173	3720	3131	30
H(21)	7027	3872	2026	30
H(23)	3433	3545	1976	26
H(24)	3586	3389	3089	26
H(26A)	2037	1910	3506	35
H(26B)	1571	600	3583	35
H(26C)	2876	830	3356	35
H(27A)	2492	-646	4496	43
H(27B)	3542	-112	4976	43
H(27C)	3786	-414	4255	43
H(28A)	1604	2322	4615	41
H(28B)	2239	1583	5198	41
H(28C)	1194	1005	4731	41

Torsion angles [°] for **3**.

C(3)-O(1)-C(2)-C(1)	55.48(15)
C(5)-C(1)-C(2)-O(1)	74.33(16)
C(4)-C(1)-C(2)-O(1)	-51.34(16)
C(2)-O(1)-C(3)-O(2)	-59.62(14)
C(2)-O(1)-C(3)-C(11)	-179.47(11)
C(4)-O(2)-C(3)-O(1)	62.39(14)
C(4)-O(2)-C(3)-C(11)	-177.96(11)
C(3)-O(2)-C(4)-C(1)	-60.44(15)
C(5)-C(1)-C(4)-O(2)	-73.07(15)
C(2)-C(1)-C(4)-O(2)	53.71(15)
C(2)-C(1)-C(5)-C(6)	-30.1(2)
C(4)-C(1)-C(5)-C(6)	92.64(17)
C(2)-C(1)-C(5)-C(10)	149.46(14)
C(4)-C(1)-C(5)-C(10)	-87.79(16)
C(10)-C(5)-C(6)-C(7)	-0.7(2)
C(1)-C(5)-C(6)-C(7)	178.85(14)
C(5)-C(6)-C(7)-C(8)	0.0(2)
C(6)-C(7)-C(8)-C(9)	0.8(2)
C(6)-C(7)-C(8)-Cl(1)	-179.73(12)
C(7)-C(8)-C(9)-C(10)	-0.8(2)
Cl(1)-C(8)-C(9)-C(10)	179.73(12)
C(8)-C(9)-C(10)-C(5)	0.0(2)
C(6)-C(5)-C(10)-C(9)	0.7(2)
C(1)-C(5)-C(10)-C(9)	-178.87(14)
O(1)-C(3)-C(11)-C(12)	-58.16(15)
O(2)-C(3)-C(11)-C(12)	-179.07(12)
O(1)-C(3)-C(11)-C(14)	62.34(15)
O(2)-C(3)-C(11)-C(14)	-58.56(16)
O(1)-C(3)-C(11)-C(13)	-176.75(11)
O(2)-C(3)-C(11)-C(13)	62.35(15)
C(17)-O(3)-C(16)-C(15)	-60.59(16)
C(19)-C(15)-C(16)-O(3)	-73.68(16)
C(18)-C(15)-C(16)-O(3)	53.63(17)
C(18)-O(4)-C(17)-O(3)	-60.19(15)
C(18)-O(4)-C(17)-C(25)	179.23(12)
C(16)-O(3)-C(17)-O(4)	63.26(15)
C(16)-O(3)-C(17)-C(25)	-176.10(12)
C(17)-O(4)-C(18)-C(15)	55.25(16)
C(19)-C(15)-C(18)-O(4)	73.29(17)
C(16)-C(15)-C(18)-O(4)	-51.05(17)
C(18)-C(15)-C(19)-C(24)	-30.0(2)
C(16)-C(15)-C(19)-C(24)	92.69(18)
C(18)-C(15)-C(19)-C(20)	152.48(14)
C(16)-C(15)-C(19)-C(20)	-84.83(17)
C(24)-C(19)-C(20)-C(21)	0.4(2)
C(15)-C(19)-C(20)-C(21)	178.03(14)
C(19)-C(20)-C(21)-C(22)	-0.3(2)
C(20)-C(21)-C(22)-C(23)	0.3(2)
C(20)-C(21)-C(22)-Cl(2)	-179.56(12)
C(21)-C(22)-C(23)-C(24)	-0.4(2)
Cl(2)-C(22)-C(23)-C(24)	179.51(12)
C(22)-C(23)-C(24)-C(19)	0.4(2)
C(20)-C(19)-C(24)-C(23)	-0.4(2)
C(15)-C(19)-C(24)-C(23)	-177.93(14)

O(4)-C(17)-C(25)-C(28)	-60.63(15)
O(3)-C(17)-C(25)-C(28)	177.83(12)
O(4)-C(17)-C(25)-C(27)	-179.20(12)
O(3)-C(17)-C(25)-C(27)	59.26(16)
O(4)-C(17)-C(25)-C(26)	59.77(15)
O(3)-C(17)-C(25)-C(26)	-61.77(15)

Symmetry transformations used to generate equivalent atoms:



The full numbering scheme of **15**. All atoms shown are depicted with 50% thermal contours. The hydrogen atoms are shown as spheres.

Crystal data and structure refinement for **15**.

Identification code	007-15080	
Empirical formula	C ₁₃ H ₁₉ NO ₂	
Formula weight	22129	
Temperature	93(2) K	
Wavelength	1.54178 Å	
Crystal system	Monoclinic	
Space group	P2 ₁ /c	
Unit cell dimensions	a = 19.1093(13) Å	α = 90°.
	b = 5.5821(2) Å	β = 92.757(7)°.
	c = 11.6158(4) Å	γ = 90°.
Volume	1237.62(10) Å ³	
Z	4	
Density (calculated)	1.188 Mg/m ³	
Absorption coefficient	0.634 mm ⁻¹	
F(000)	480	
Crystal size	0.180 x 0.080 x 0.040 mm ³	
Θ range for data collection	6.959 to 66.580°.	
Index ranges	-22 ≤ h ≤ 21, -6 ≤ k ≤ 6, -13 ≤ l ≤ 13	
Reflections collected	26885	
Independent reflections	2179 [R(int) = 0.0755]	
Completeness to θ = 66.580°	99.9 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.975 and 0.766	
Refinement method	Full-matrix least-squares on F ²	
Data / restraints / parameters	2179 / 0 / 148	
Goodness-of-fit on F ²	1.094	
Final R indices [I>2σ(I)]	R1 = 0.0326, wR2 = 0.0879	
R indices (all data)	R1 = 0.0350, wR2 = 0.0895	
Largest diff. peak and hole	0.173 and -0.155 e.Å ⁻³	

Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for **15**. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)
O(3)	7864(1)	5376(1)	2166(1)	24(1)
O(5)	7743(1)	2202(1)	3449(1)	24(1)
N(1)	5955(1)	6145(2)	2034(1)	24(1)
C(1)	6808(1)	2977(2)	2009(1)	24(1)
C(2)	7348(1)	4420(2)	1363(1)	25(1)
C(4)	8215(1)	3534(2)	2802(1)	23(1)
C(6)	7209(1)	1093(2)	2727(1)	26(1)
C(7)	6357(1)	4651(2)	2684(1)	22(1)
C(8)	6360(1)	4709(2)	3879(1)	28(1)
C(9)	5939(1)	6345(2)	4414(1)	32(1)
C(10)	5524(1)	7876(2)	3752(1)	29(1)
C(11)	5549(1)	7704(2)	2568(1)	27(1)
C(12)	8770(1)	4658(2)	3616(1)	26(1)
C(13)	8434(1)	6331(2)	4477(1)	30(1)
C(14)	9279(1)	6061(2)	2892(1)	34(1)
C(15)	9168(1)	2644(2)	4265(1)	34(1)

Bond lengths [Å] and angles [°] for **15**.

O(3)-C(4)	1.4164(13)
O(3)-C(2)	1.4274(13)
O(5)-C(4)	1.4126(12)
O(5)-C(6)	1.4306(13)
N(1)-C(11)	1.3375(14)
N(1)-C(7)	1.3420(14)
C(1)-C(7)	1.5150(14)
C(1)-C(6)	1.5256(15)
C(1)-C(2)	1.5328(14)
C(1)-H(1)	1.0000
C(2)-H(2A)	0.9900
C(2)-H(2B)	0.9900
C(4)-C(12)	1.5217(16)
C(4)-H(4)	1.0000
C(6)-H(6A)	0.9900
C(6)-H(6B)	0.9900
C(7)-C(8)	1.3887(15)
C(8)-C(9)	1.3843(16)
C(8)-H(8)	0.9500
C(9)-C(10)	1.3751(16)
C(9)-H(9)	0.9500
C(10)-C(11)	1.3819(16)
C(10)-H(10)	0.9500
C(11)-H(11)	0.9500
C(12)-C(14)	1.5312(15)
C(12)-C(13)	1.5328(15)
C(12)-C(15)	1.5342(15)
C(13)-H(13A)	0.9800
C(13)-H(13B)	0.9800
C(13)-H(13C)	0.9800
C(14)-H(14A)	0.9800
C(14)-H(14B)	0.9800
C(14)-H(14C)	0.9800
C(15)-H(15A)	0.9800
C(15)-H(15B)	0.9800
C(15)-H(15C)	0.9800
C(4)-O(3)-C(2)	111.38(8)
C(4)-O(5)-C(6)	111.84(8)
C(11)-N(1)-C(7)	118.21(9)
C(7)-C(1)-C(6)	115.21(8)
C(7)-C(1)-C(2)	110.02(8)
C(6)-C(1)-C(2)	107.31(9)
C(7)-C(1)-H(1)	108.0
C(6)-C(1)-H(1)	108.0
C(2)-C(1)-H(1)	108.0
O(3)-C(2)-C(1)	109.66(8)
O(3)-C(2)-H(2A)	109.7
C(1)-C(2)-H(2A)	109.7
O(3)-C(2)-H(2B)	109.7
C(1)-C(2)-H(2B)	109.7
H(2A)-C(2)-H(2B)	108.2
O(5)-C(4)-O(3)	111.15(8)
O(5)-C(4)-C(12)	109.32(8)

O(3)-C(4)-C(12)	108.89(8)
O(5)-C(4)-H(4)	109.2
O(3)-C(4)-H(4)	109.2
C(12)-C(4)-H(4)	109.2
O(5)-C(6)-C(1)	110.32(8)
O(5)-C(6)-H(6A)	109.6
C(1)-C(6)-H(6A)	109.6
O(5)-C(6)-H(6B)	109.6
C(1)-C(6)-H(6B)	109.6
H(6A)-C(6)-H(6B)	108.1
N(1)-C(7)-C(8)	121.49(10)
N(1)-C(7)-C(1)	114.65(9)
C(8)-C(7)-C(1)	123.85(10)
C(9)-C(8)-C(7)	119.36(11)
C(9)-C(8)-H(8)	120.3
C(7)-C(8)-H(8)	120.3
C(10)-C(9)-C(8)	119.35(10)
C(10)-C(9)-H(9)	120.3
C(8)-C(9)-H(9)	120.3
C(9)-C(10)-C(11)	117.87(10)
C(9)-C(10)-H(10)	121.1
C(11)-C(10)-H(10)	121.1
N(1)-C(11)-C(10)	123.72(11)
N(1)-C(11)-H(11)	118.1
C(10)-C(11)-H(11)	118.1
C(4)-C(12)-C(14)	108.18(9)
C(4)-C(12)-C(13)	110.75(9)
C(14)-C(12)-C(13)	110.15(9)
C(4)-C(12)-C(15)	108.49(9)
C(14)-C(12)-C(15)	109.42(9)
C(13)-C(12)-C(15)	109.81(9)
C(12)-C(13)-H(13A)	109.5
C(12)-C(13)-H(13B)	109.5
H(13A)-C(13)-H(13B)	109.5
C(12)-C(13)-H(13C)	109.5
H(13A)-C(13)-H(13C)	109.5
H(13B)-C(13)-H(13C)	109.5
C(12)-C(14)-H(14A)	109.5
C(12)-C(14)-H(14B)	109.5
H(14A)-C(14)-H(14B)	109.5
C(12)-C(14)-H(14C)	109.5
H(14A)-C(14)-H(14C)	109.5
H(14B)-C(14)-H(14C)	109.5
C(12)-C(15)-H(15A)	109.5
C(12)-C(15)-H(15B)	109.5
H(15A)-C(15)-H(15B)	109.5
C(12)-C(15)-H(15C)	109.5
H(15A)-C(15)-H(15C)	109.5
H(15B)-C(15)-H(15C)	109.5

Symmetry transformations used to generate equivalent atoms:

Anisotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for **15**. The anisotropic displacement factor exponent takes the form: $-2\pi^2 [h^2 a^{*2} U^{11} + \dots + 2 h k a^* b^* U^{12}]$

	U ¹¹	U ²²	U ³³	U ²³	U ¹³	U ¹²
O(3)	25(1)	23(1)	23(1)	1(1)	2(1)	-1(1)
O(5)	23(1)	23(1)	27(1)	2(1)	0(1)	-3(1)
N(1)	23(1)	29(1)	21(1)	2(1)	3(1)	0(1)
C(1)	25(1)	25(1)	21(1)	-4(1)	0(1)	-2(1)
C(2)	26(1)	31(1)	19(1)	-3(1)	3(1)	2(1)
C(4)	23(1)	21(1)	26(1)	1(1)	5(1)	1(1)
C(6)	25(1)	23(1)	32(1)	-3(1)	0(1)	-3(1)
C(7)	20(1)	24(1)	21(1)	0(1)	1(1)	-4(1)
C(8)	28(1)	36(1)	20(1)	2(1)	0(1)	3(1)
C(9)	32(1)	44(1)	19(1)	-4(1)	3(1)	1(1)
C(10)	26(1)	32(1)	29(1)	-6(1)	7(1)	1(1)
C(11)	25(1)	29(1)	28(1)	3(1)	4(1)	2(1)
C(12)	25(1)	23(1)	31(1)	0(1)	1(1)	-2(1)
C(13)	36(1)	25(1)	28(1)	-1(1)	-1(1)	-3(1)
C(14)	29(1)	33(1)	41(1)	0(1)	4(1)	-7(1)
C(15)	29(1)	28(1)	45(1)	1(1)	-7(1)	-2(1)

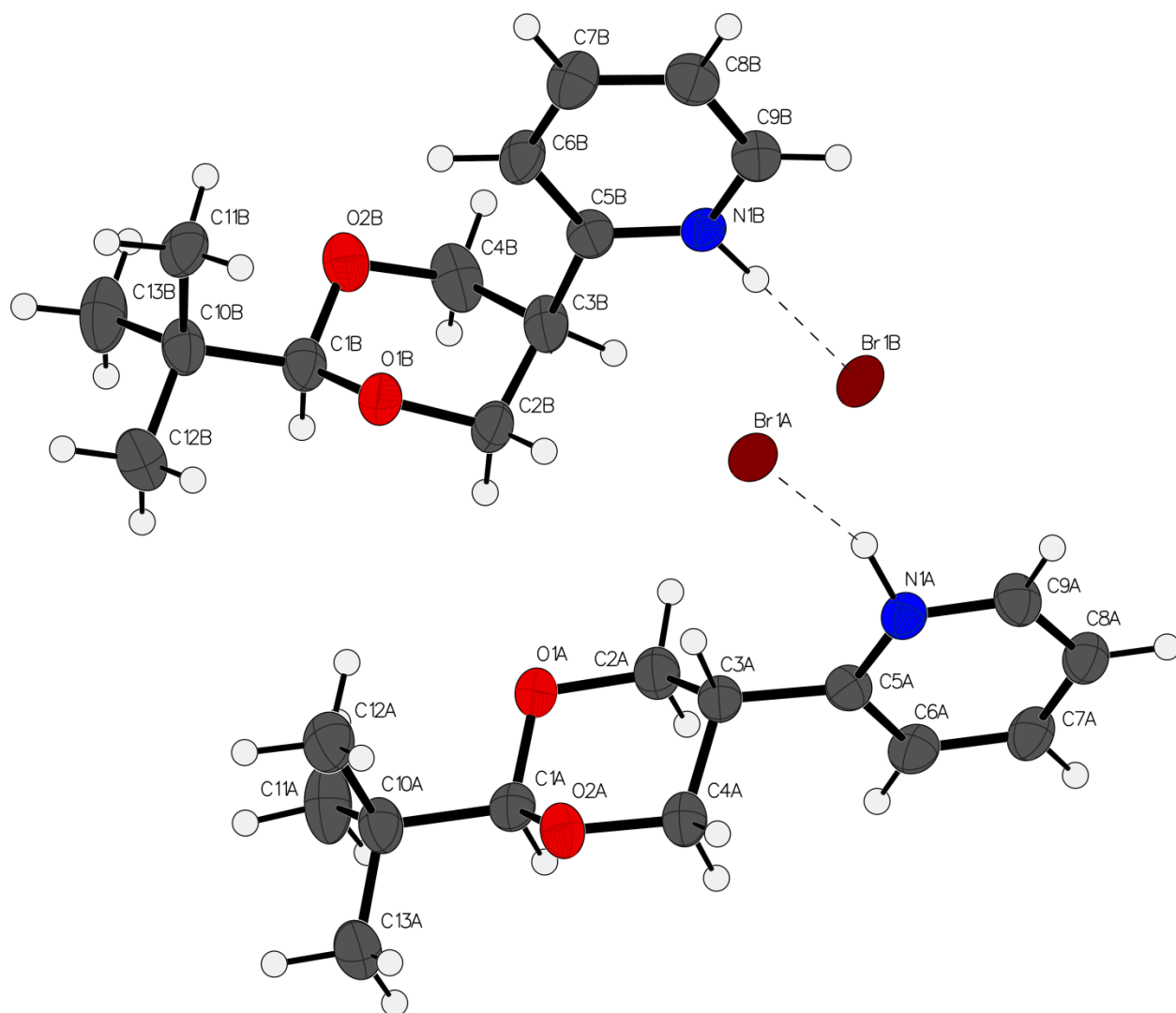
Hydrogen coordinates ($\times 10^4$) and isotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for **15**.

	x	y	z	U(eq)
H(1)	6497	2127	1425	28
H(2A)	7576	3371	805	30
H(2B)	7111	5741	930	30
H(4)	8448	2437	2257	28
H(6A)	6881	216	3209	32
H(6B)	7425	-76	2209	32
H(8)	6647	3635	4325	34
H(9)	5936	6411	5231	38
H(10)	5230	9015	4097	35
H(11)	5262	8752	2107	33
H(13A)	8194	7644	4059	45
H(13B)	8797	6988	5010	45
H(13C)	8094	5431	4911	45
H(14A)	9476	4990	2322	51
H(14B)	9659	6713	3396	51
H(14C)	9029	7377	2494	51
H(15A)	8847	1787	4753	51
H(15B)	9552	3332	4747	51
H(15C)	9358	1527	3710	51

Torsion angles [°] for **15**.

C(4)-O(3)-C(2)-C(1)	59.44(10)
C(7)-C(1)-C(2)-O(3)	70.76(10)
C(6)-C(1)-C(2)-O(3)	-55.28(10)
C(6)-O(5)-C(4)-O(3)	59.99(10)
C(6)-O(5)-C(4)-C(12)	-179.79(8)
C(2)-O(3)-C(4)-O(5)	-61.12(10)
C(2)-O(3)-C(4)-C(12)	178.40(8)
C(4)-O(5)-C(6)-C(1)	-57.61(10)
C(7)-C(1)-C(6)-O(5)	-68.55(11)
C(2)-C(1)-C(6)-O(5)	54.34(10)
C(11)-N(1)-C(7)-C(8)	-0.28(15)
C(11)-N(1)-C(7)-C(1)	-179.03(9)
C(6)-C(1)-C(7)-N(1)	-173.78(9)
C(2)-C(1)-C(7)-N(1)	64.78(11)
C(6)-C(1)-C(7)-C(8)	7.50(15)
C(2)-C(1)-C(7)-C(8)	-113.93(11)
N(1)-C(7)-C(8)-C(9)	-0.09(17)
C(1)-C(7)-C(8)-C(9)	178.54(10)
C(7)-C(8)-C(9)-C(10)	0.27(17)
C(8)-C(9)-C(10)-C(11)	-0.06(17)
C(7)-N(1)-C(11)-C(10)	0.51(16)
C(9)-C(10)-C(11)-N(1)	-0.34(18)
O(5)-C(4)-C(12)-C(14)	179.25(8)
O(3)-C(4)-C(12)-C(14)	-59.15(10)
O(5)-C(4)-C(12)-C(13)	-59.94(11)
O(3)-C(4)-C(12)-C(13)	61.66(11)
O(5)-C(4)-C(12)-C(15)	60.64(11)
O(3)-C(4)-C(12)-C(15)	-177.76(8)

Symmetry transformations used to generate equivalent atoms:



The complete numbering scheme of a co-crystal of compounds **17** and **18** with 50% thermal ellipsoid probability levels. The hydrogen atoms are shown as circles for clarity. Dashed lines highlight hydrogen bond interactions.

Crystal data and structure refinement for co-crystal of compounds **17** and **18**.

Identification code	007-16102	
Empirical formula	C ₁₃ H ₂₀ Br N O ₂	
Formula weight	302.21	
Temperature	93(2) K	
Wavelength	1.54178 Å	
Crystal system	Monoclinic	
Space group	P2 ₁ /n	
Unit cell dimensions	a = 6.9215(5) Å	α = 90°.
	b = 9.4954(7) Å	β = 94.141(4)°.
	c = 44.491(3) Å	γ = 90°.
Volume	2916.4(4) Å ³	
Z	8	
Density (calculated)	1.377 Mg/m ³	
Absorption coefficient	3.775 mm ⁻¹	
F(000)	1248	
Crystal size	0.200 x 0.200 x 0.010 mm ³	
Theta range for data collection	3.985 to 68.350°.	
Index ranges	-8 ≤ h ≤ 8, -10 ≤ k ≤ 10, -53 ≤ l ≤ 53	
Reflections collected	98200	
Independent reflections	5219 [R(int) = 0.1012]	
Completeness to theta = 67.679°	98.5 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	1.000 and 0.586	
Refinement method	Full-matrix least-squares on F ²	
Data / restraints / parameters	5219 / 2 / 321	
Goodness-of-fit on F ²	1.266	
Final R indices [I > 2σ(I)]	R1 = 0.0576, wR2 = 0.1280	
R indices (all data)	R1 = 0.0590, wR2 = 0.1285	
Largest diff. peak and hole	0.580 and -0.768 e.Å ⁻³	

Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement parameters ($\text{\AA}^2 \times 10^3$)
for co-crystal of compounds **17** and **18**. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)
Br(1A)	6911(1)	6938(1)	3079(1)	32(1)
O(1A)	5544(5)	3792(4)	4027(1)	34(1)
O(2A)	8897(5)	3749(4)	4029(1)	35(1)
N(1A)	6898(6)	3568(5)	3005(1)	30(1)
C(1A)	7278(8)	3344(6)	4183(1)	31(1)
C(2A)	5266(8)	3147(6)	3737(1)	36(1)
C(3A)	6974(8)	3499(5)	3553(1)	30(1)
C(4A)	8837(8)	3119(6)	3739(1)	35(1)
C(5A)	6829(7)	2768(6)	3253(1)	29(1)
C(6A)	6668(8)	1323(6)	3216(1)	35(1)
C(7A)	6562(8)	754(6)	2933(1)	36(1)
C(8A)	6626(8)	1607(6)	2682(1)	34(1)
C(9A)	6806(8)	3042(6)	2728(1)	35(1)
C(10A)	7467(9)	4009(6)	4499(1)	37(1)
C(11A)	5729(11)	3515(8)	4669(1)	56(2)
C(12A)	7471(11)	5608(6)	4477(1)	47(2)
C(13A)	9344(11)	3502(8)	4664(1)	55(2)
Br(1B)	1868(1)	4076(1)	2965(1)	33(1)
O(1B)	3785(6)	8071(4)	3975(1)	38(1)
O(2B)	458(6)	8164(4)	3992(1)	37(1)
N(1B)	2010(6)	7460(4)	3057(1)	27(1)
C(1B)	2239(8)	8040(6)	4166(1)	35(1)
C(2B)	3681(10)	6879(6)	3775(1)	46(2)
C(3B)	1785(10)	6855(6)	3579(1)	41(1)
C(4B)	135(10)	7018(7)	3786(1)	47(2)
C(5B)	1762(8)	7937(5)	3331(1)	31(1)
C(6B)	1539(9)	9383(6)	3367(1)	38(1)
C(7B)	1559(9)	10256(6)	3124(1)	39(1)
C(8B)	1839(9)	9709(6)	2841(1)	39(1)
C(9B)	2072(8)	8295(6)	2813(1)	32(1)
C(10B)	2465(9)	9217(6)	4397(1)	36(1)
C(11B)	2385(9)	10645(6)	4237(1)	41(1)
C(12B)	4411(10)	9054(8)	4581(1)	54(2)
C(13B)	801(11)	9100(8)	4606(1)	55(2)

Bond lengths [Å] and angles [°] for co-crystal of compounds **17** and **18**

O(1A)-C(1A)	1.408(6)
O(1A)-C(2A)	1.427(6)
O(2A)-C(1A)	1.409(6)
O(2A)-C(4A)	1.419(6)
N(1A)-C(9A)	1.325(7)
N(1A)-C(5A)	1.342(6)
N(1A)-H(1A)	0.99(2)
C(1A)-C(10A)	1.540(7)
C(1A)-H(1AA)	1.0000
C(2A)-C(3A)	1.523(7)
C(2A)-H(2AA)	0.9900
C(2A)-H(2AB)	0.9900
C(3A)-C(5A)	1.501(7)
C(3A)-C(4A)	1.525(7)
C(3A)-H(3A)	1.0000
C(4A)-H(4AA)	0.9900
C(4A)-H(4AB)	0.9900
C(5A)-C(6A)	1.386(8)
C(6A)-C(7A)	1.368(8)
C(6A)-H(6A)	0.9500
C(7A)-C(8A)	1.385(8)
C(7A)-H(7A)	0.9500
C(8A)-C(9A)	1.382(8)
C(8A)-H(8A)	0.9500
C(9A)-H(9A)	0.9500
C(10A)-C(12A)	1.521(8)
C(10A)-C(13A)	1.522(9)
C(10A)-C(11A)	1.539(8)
C(11A)-H(11A)	0.9800
C(11A)-H(11B)	0.9800
C(11A)-H(11C)	0.9800
C(12A)-H(12A)	0.9800
C(12A)-H(12B)	0.9800
C(12A)-H(12C)	0.9800
C(13A)-H(13A)	0.9800
C(13A)-H(13B)	0.9800
C(13A)-H(13C)	0.9800
O(1B)-C(1B)	1.413(6)
O(1B)-C(2B)	1.439(7)
O(2B)-C(1B)	1.413(7)
O(2B)-C(4B)	1.430(7)
N(1B)-C(5B)	1.321(7)
N(1B)-C(9B)	1.348(7)
N(1B)-H(1B)	1.01(2)
C(1B)-C(10B)	1.518(7)
C(1B)-H(1BA)	1.0000
C(2B)-C(3B)	1.523(9)
C(2B)-H(2BA)	0.9900
C(2B)-H(2BB)	0.9900
C(3B)-C(5B)	1.506(7)
C(3B)-C(4B)	1.526(9)
C(3B)-H(3B)	1.0000
C(4B)-H(4BA)	0.9900
C(4B)-H(4BB)	0.9900

C(5B)-C(6B)	1.392(8)
C(6B)-C(7B)	1.364(8)
C(6B)-H(6B)	0.9500
C(7B)-C(8B)	1.387(8)
C(7B)-H(7B)	0.9500
C(8B)-C(9B)	1.358(8)
C(8B)-H(8B)	0.9500
C(9B)-H(9B)	0.9500
C(10B)-C(11B)	1.530(8)
C(10B)-C(12B)	1.532(9)
C(10B)-C(13B)	1.537(8)
C(11B)-H(11D)	0.9800
C(11B)-H(11E)	0.9800
C(11B)-H(11F)	0.9800
C(12B)-H(12D)	0.9800
C(12B)-H(12E)	0.9800
C(12B)-H(12F)	0.9800
C(13B)-H(13D)	0.9800
C(13B)-H(13E)	0.9800
C(13B)-H(13F)	0.9800
C(1A)-O(1A)-C(2A)	111.8(4)
C(1A)-O(2A)-C(4A)	110.9(4)
C(9A)-N(1A)-C(5A)	123.2(5)
C(9A)-N(1A)-H(1A)	110(5)
C(5A)-N(1A)-H(1A)	120(5)
O(1A)-C(1A)-O(2A)	110.9(4)
O(1A)-C(1A)-C(10A)	109.9(4)
O(2A)-C(1A)-C(10A)	108.4(4)
O(1A)-C(1A)-H(1AA)	109.2
O(2A)-C(1A)-H(1AA)	109.2
C(10A)-C(1A)-H(1AA)	109.2
O(1A)-C(2A)-C(3A)	109.4(4)
O(1A)-C(2A)-H(2AA)	109.8
C(3A)-C(2A)-H(2AA)	109.8
O(1A)-C(2A)-H(2AB)	109.8
C(3A)-C(2A)-H(2AB)	109.8
H(2AA)-C(2A)-H(2AB)	108.2
C(5A)-C(3A)-C(2A)	111.9(4)
C(5A)-C(3A)-C(4A)	111.9(4)
C(2A)-C(3A)-C(4A)	108.4(4)
C(5A)-C(3A)-H(3A)	108.2
C(2A)-C(3A)-H(3A)	108.2
C(4A)-C(3A)-H(3A)	108.2
O(2A)-C(4A)-C(3A)	111.2(4)
O(2A)-C(4A)-H(4AA)	109.4
C(3A)-C(4A)-H(4AA)	109.4
O(2A)-C(4A)-H(4AB)	109.4
C(3A)-C(4A)-H(4AB)	109.4
H(4AA)-C(4A)-H(4AB)	108.0
N(1A)-C(5A)-C(6A)	118.2(5)
N(1A)-C(5A)-C(3A)	117.7(5)
C(6A)-C(5A)-C(3A)	124.1(5)
C(7A)-C(6A)-C(5A)	119.8(5)
C(7A)-C(6A)-H(6A)	120.1
C(5A)-C(6A)-H(6A)	120.1

C(6A)-C(7A)-C(8A)	120.7(5)
C(6A)-C(7A)-H(7A)	119.6
C(8A)-C(7A)-H(7A)	119.6
C(9A)-C(8A)-C(7A)	117.6(5)
C(9A)-C(8A)-H(8A)	121.2
C(7A)-C(8A)-H(8A)	121.2
N(1A)-C(9A)-C(8A)	120.6(5)
N(1A)-C(9A)-H(9A)	119.7
C(8A)-C(9A)-H(9A)	119.7
C(12A)-C(10A)-C(13A)	109.9(5)
C(12A)-C(10A)-C(11A)	109.9(5)
C(13A)-C(10A)-C(11A)	109.8(5)
C(12A)-C(10A)-C(1A)	110.5(5)
C(13A)-C(10A)-C(1A)	108.8(5)
C(11A)-C(10A)-C(1A)	107.8(5)
C(10A)-C(11A)-H(11A)	109.5
C(10A)-C(11A)-H(11B)	109.5
H(11A)-C(11A)-H(11B)	109.5
C(10A)-C(11A)-H(11C)	109.5
H(11A)-C(11A)-H(11C)	109.5
H(11B)-C(11A)-H(11C)	109.5
C(10A)-C(12A)-H(12A)	109.5
C(10A)-C(12A)-H(12B)	109.5
H(12A)-C(12A)-H(12B)	109.5
C(10A)-C(12A)-H(12C)	109.5
H(12A)-C(12A)-H(12C)	109.5
H(12B)-C(12A)-H(12C)	109.5
C(10A)-C(13A)-H(13A)	109.5
C(10A)-C(13A)-H(13B)	109.5
H(13A)-C(13A)-H(13B)	109.5
C(10A)-C(13A)-H(13C)	109.5
H(13A)-C(13A)-H(13C)	109.5
H(13B)-C(13A)-H(13C)	109.5
C(1B)-O(1B)-C(2B)	110.4(5)
C(1B)-O(2B)-C(4B)	112.2(5)
C(5B)-N(1B)-C(9B)	123.6(5)
C(5B)-N(1B)-H(1B)	120(3)
C(9B)-N(1B)-H(1B)	116(3)
O(2B)-C(1B)-O(1B)	109.7(4)
O(2B)-C(1B)-C(10B)	110.7(5)
O(1B)-C(1B)-C(10B)	110.1(5)
O(2B)-C(1B)-H(1BA)	108.8
O(1B)-C(1B)-H(1BA)	108.8
C(10B)-C(1B)-H(1BA)	108.8
O(1B)-C(2B)-C(3B)	111.7(5)
O(1B)-C(2B)-H(2BA)	109.3
C(3B)-C(2B)-H(2BA)	109.3
O(1B)-C(2B)-H(2BB)	109.3
C(3B)-C(2B)-H(2BB)	109.3
H(2BA)-C(2B)-H(2BB)	107.9
C(5B)-C(3B)-C(2B)	111.9(5)
C(5B)-C(3B)-C(4B)	113.8(5)
C(2B)-C(3B)-C(4B)	107.7(5)
C(5B)-C(3B)-H(3B)	107.7
C(2B)-C(3B)-H(3B)	107.7
C(4B)-C(3B)-H(3B)	107.7

O(2B)-C(4B)-C(3B)	112.0(5)
O(2B)-C(4B)-H(4BA)	109.2
C(3B)-C(4B)-H(4BA)	109.2
O(2B)-C(4B)-H(4BB)	109.2
C(3B)-C(4B)-H(4BB)	109.2
H(4BA)-C(4B)-H(4BB)	107.9
N(1B)-C(5B)-C(6B)	117.8(5)
N(1B)-C(5B)-C(3B)	116.4(5)
C(6B)-C(5B)-C(3B)	125.7(5)
C(7B)-C(6B)-C(5B)	120.0(5)
C(7B)-C(6B)-H(6B)	120.0
C(5B)-C(6B)-H(6B)	120.0
C(6B)-C(7B)-C(8B)	120.1(5)
C(6B)-C(7B)-H(7B)	119.9
C(8B)-C(7B)-H(7B)	119.9
C(9B)-C(8B)-C(7B)	118.5(5)
C(9B)-C(8B)-H(8B)	120.7
C(7B)-C(8B)-H(8B)	120.7
N(1B)-C(9B)-C(8B)	119.9(5)
N(1B)-C(9B)-H(9B)	120.1
C(8B)-C(9B)-H(9B)	120.1
C(1B)-C(10B)-C(11B)	109.9(4)
C(1B)-C(10B)-C(12B)	109.3(5)
C(11B)-C(10B)-C(12B)	109.8(5)
C(1B)-C(10B)-C(13B)	108.1(5)
C(11B)-C(10B)-C(13B)	110.0(5)
C(12B)-C(10B)-C(13B)	109.7(5)
C(10B)-C(11B)-H(11D)	109.5
C(10B)-C(11B)-H(11E)	109.5
H(11D)-C(11B)-H(11E)	109.5
C(10B)-C(11B)-H(11F)	109.5
H(11D)-C(11B)-H(11F)	109.5
H(11E)-C(11B)-H(11F)	109.5
C(10B)-C(12B)-H(12D)	109.5
C(10B)-C(12B)-H(12E)	109.5
H(12D)-C(12B)-H(12E)	109.5
C(10B)-C(12B)-H(12F)	109.5
H(12D)-C(12B)-H(12F)	109.5
H(12E)-C(12B)-H(12F)	109.5
C(10B)-C(13B)-H(13D)	109.5
C(10B)-C(13B)-H(13E)	109.5
H(13D)-C(13B)-H(13E)	109.5
C(10B)-C(13B)-H(13F)	109.5
H(13D)-C(13B)-H(13F)	109.5
H(13E)-C(13B)-H(13F)	109.5

Symmetry transformations used to generate equivalent atoms:

Anisotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for co-crystal of compounds **17** and **18**. The anisotropic displacement factor exponent takes the form: $-2\pi^2 [h^2 a^{*2} U^{11} + \dots + 2 h k a^* b^* U^{12}]$

	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
Br(1A)	38(1)	23(1)	36(1)	2(1)	6(1)	0(1)
O(1A)	38(2)	38(2)	28(2)	-5(2)	3(2)	6(2)
O(2A)	42(2)	33(2)	29(2)	-4(2)	3(2)	-6(2)
N(1A)	34(2)	25(2)	30(2)	1(2)	5(2)	0(2)
C(1A)	41(3)	21(3)	30(3)	2(2)	5(2)	-2(2)
C(2A)	43(3)	35(3)	30(3)	-1(2)	4(2)	1(3)
C(3A)	46(3)	19(3)	26(3)	3(2)	4(2)	0(2)
C(4A)	42(3)	34(3)	29(3)	-2(2)	6(2)	-3(3)
C(5A)	31(3)	28(3)	28(3)	4(2)	6(2)	-1(2)
C(6A)	46(3)	25(3)	36(3)	5(2)	8(2)	2(2)
C(7A)	45(3)	26(3)	39(3)	-5(2)	7(2)	0(2)
C(8A)	40(3)	30(3)	34(3)	-3(2)	5(2)	0(2)
C(9A)	43(3)	33(3)	28(3)	3(2)	5(2)	-3(3)
C(10A)	54(4)	31(3)	26(3)	0(2)	6(2)	-3(3)
C(11A)	79(5)	54(4)	37(3)	-10(3)	20(3)	-19(4)
C(12A)	72(5)	29(3)	40(3)	-3(3)	1(3)	-3(3)
C(13A)	76(5)	53(4)	35(3)	-9(3)	-7(3)	12(4)
Br(1B)	39(1)	23(1)	39(1)	-4(1)	8(1)	-1(1)
O(1B)	48(2)	38(2)	29(2)	-4(2)	5(2)	7(2)
O(2B)	45(2)	36(2)	29(2)	-1(2)	6(2)	-9(2)
N(1B)	32(2)	22(2)	29(2)	2(2)	4(2)	1(2)
C(1B)	52(3)	27(3)	27(3)	1(2)	6(2)	0(3)
C(2B)	76(5)	34(3)	29(3)	-4(2)	5(3)	20(3)
C(3B)	76(4)	18(3)	28(3)	1(2)	6(3)	-4(3)
C(4B)	70(4)	37(3)	34(3)	2(3)	6(3)	-20(3)
C(5B)	40(3)	21(3)	31(3)	2(2)	2(2)	-4(2)
C(6B)	58(4)	23(3)	34(3)	-2(2)	8(3)	2(3)
C(7B)	46(3)	27(3)	44(3)	-1(2)	11(3)	-6(3)
C(8B)	48(3)	34(3)	35(3)	8(2)	6(2)	0(3)
C(9B)	36(3)	29(3)	33(3)	3(2)	5(2)	-5(2)
C(10B)	53(4)	29(3)	27(3)	-3(2)	4(2)	-5(3)
C(11B)	59(4)	24(3)	40(3)	-4(2)	6(3)	3(3)
C(12B)	66(4)	60(4)	35(3)	-6(3)	-5(3)	4(4)
C(13B)	81(5)	50(4)	38(3)	-7(3)	23(3)	-8(4)

Hydrogen coordinates ($\times 10^4$) and isotropic displacement parameters ($\text{\AA}^2 \times 10^3$)
for co-crystal of compounds **17** and **18**.

	x	y	z	U(eq)
H(1A)	6360(120)	4540(40)	3000(20)	110(30)
H(1AA)	7261	2295	4203	37
H(2AA)	4050	3495	3632	43
H(2AB)	5161	2114	3760	43
H(3A)	6973	4538	3516	36
H(4AA)	8926	2083	3761	42
H(4AB)	9964	3443	3632	42
H(6A)	6631	728	3388	42
H(7A)	6443	-237	2909	44
H(8A)	6548	1221	2484	41
H(9A)	6865	3656	2561	42
H(11A)	4532	3905	4572	84
H(11B)	5886	3841	4878	84
H(11C)	5664	2484	4666	84
H(12A)	8601	5916	4374	71
H(12B)	7528	6014	4680	71
H(12C)	6285	5923	4363	71
H(13A)	9357	2471	4669	83
H(13B)	9435	3869	4870	83
H(13C)	10447	3841	4558	83
H(1B)	2070(90)	6420(20)	3020(13)	45(17)
H(1BA)	2262	7117	4275	42
H(2BA)	3798	6001	3895	56
H(2BB)	4779	6915	3645	56
H(3B)	1660	5905	3482	49
H(4BA)	-1092	7177	3662	56
H(4BB)	0	6135	3901	56
H(6B)	1373	9762	3561	46
H(7B)	1381	11240	3148	46
H(8B)	1868	10309	2670	47
H(9B)	2277	7896	2622	39
H(11D)	3378	10679	4091	62
H(11E)	2623	11398	4386	62
H(11F)	1104	10774	4132	62
H(12D)	4462	8132	4680	81
H(12E)	4547	9799	4733	81
H(12F)	5468	9126	4446	81
H(13D)	-439	9234	4489	83
H(13E)	955	9825	4763	83
H(13F)	827	8167	4700	83

Torsion angles [°] for co-crystal of compounds **17** and **18**.

C(2A)-O(1A)-C(1A)-O(2A)	62.9(5)
C(2A)-O(1A)-C(1A)-C(10A)	-177.3(4)
C(4A)-O(2A)-C(1A)-O(1A)	-61.5(5)
C(4A)-O(2A)-C(1A)-C(10A)	177.7(4)
C(1A)-O(1A)-C(2A)-C(3A)	-58.5(6)
O(1A)-C(2A)-C(3A)-C(5A)	176.1(4)
O(1A)-C(2A)-C(3A)-C(4A)	52.3(6)
C(1A)-O(2A)-C(4A)-C(3A)	57.2(6)
C(5A)-C(3A)-C(4A)-O(2A)	-176.4(4)
C(2A)-C(3A)-C(4A)-O(2A)	-52.6(6)
C(9A)-N(1A)-C(5A)-C(6A)	0.5(8)
C(9A)-N(1A)-C(5A)-C(3A)	179.2(5)
C(2A)-C(3A)-C(5A)-N(1A)	124.7(5)
C(4A)-C(3A)-C(5A)-N(1A)	-113.5(5)
C(2A)-C(3A)-C(5A)-C(6A)	-56.6(7)
C(4A)-C(3A)-C(5A)-C(6A)	65.2(7)
N(1A)-C(5A)-C(6A)-C(7A)	-0.8(8)
C(3A)-C(5A)-C(6A)-C(7A)	-179.4(5)
C(5A)-C(6A)-C(7A)-C(8A)	0.4(9)
C(6A)-C(7A)-C(8A)-C(9A)	0.2(9)
C(5A)-N(1A)-C(9A)-C(8A)	0.1(8)
C(7A)-C(8A)-C(9A)-N(1A)	-0.5(9)
O(1A)-C(1A)-C(10A)-C(12A)	-59.5(6)
O(2A)-C(1A)-C(10A)-C(12A)	61.9(6)
O(1A)-C(1A)-C(10A)-C(13A)	179.7(5)
O(2A)-C(1A)-C(10A)-C(13A)	-59.0(6)
O(1A)-C(1A)-C(10A)-C(11A)	60.7(6)
O(2A)-C(1A)-C(10A)-C(11A)	-178.0(5)
C(4B)-O(2B)-C(1B)-O(1B)	62.2(5)
C(4B)-O(2B)-C(1B)-C(10B)	-176.0(4)
C(2B)-O(1B)-C(1B)-O(2B)	-63.4(5)
C(2B)-O(1B)-C(1B)-C(10B)	174.5(4)
C(1B)-O(1B)-C(2B)-C(3B)	59.4(6)
O(1B)-C(2B)-C(3B)-C(5B)	75.0(6)
O(1B)-C(2B)-C(3B)-C(4B)	-50.8(6)
C(1B)-O(2B)-C(4B)-C(3B)	-56.0(6)
C(5B)-C(3B)-C(4B)-O(2B)	-75.8(6)
C(2B)-C(3B)-C(4B)-O(2B)	48.8(6)
C(9B)-N(1B)-C(5B)-C(6B)	0.5(8)
C(9B)-N(1B)-C(5B)-C(3B)	-178.4(5)
C(2B)-C(3B)-C(5B)-N(1B)	104.2(6)
C(4B)-C(3B)-C(5B)-N(1B)	-133.5(5)
C(2B)-C(3B)-C(5B)-C(6B)	-74.6(7)
C(4B)-C(3B)-C(5B)-C(6B)	47.8(8)
N(1B)-C(5B)-C(6B)-C(7B)	0.7(9)
C(3B)-C(5B)-C(6B)-C(7B)	179.5(6)
C(5B)-C(6B)-C(7B)-C(8B)	-1.3(9)
C(6B)-C(7B)-C(8B)-C(9B)	0.6(9)
C(5B)-N(1B)-C(9B)-C(8B)	-1.1(8)
C(7B)-C(8B)-C(9B)-N(1B)	0.5(9)
O(2B)-C(1B)-C(10B)-C(11B)	-59.2(6)
O(1B)-C(1B)-C(10B)-C(11B)	62.2(6)
O(2B)-C(1B)-C(10B)-C(12B)	-179.8(5)
O(1B)-C(1B)-C(10B)-C(12B)	-58.3(6)

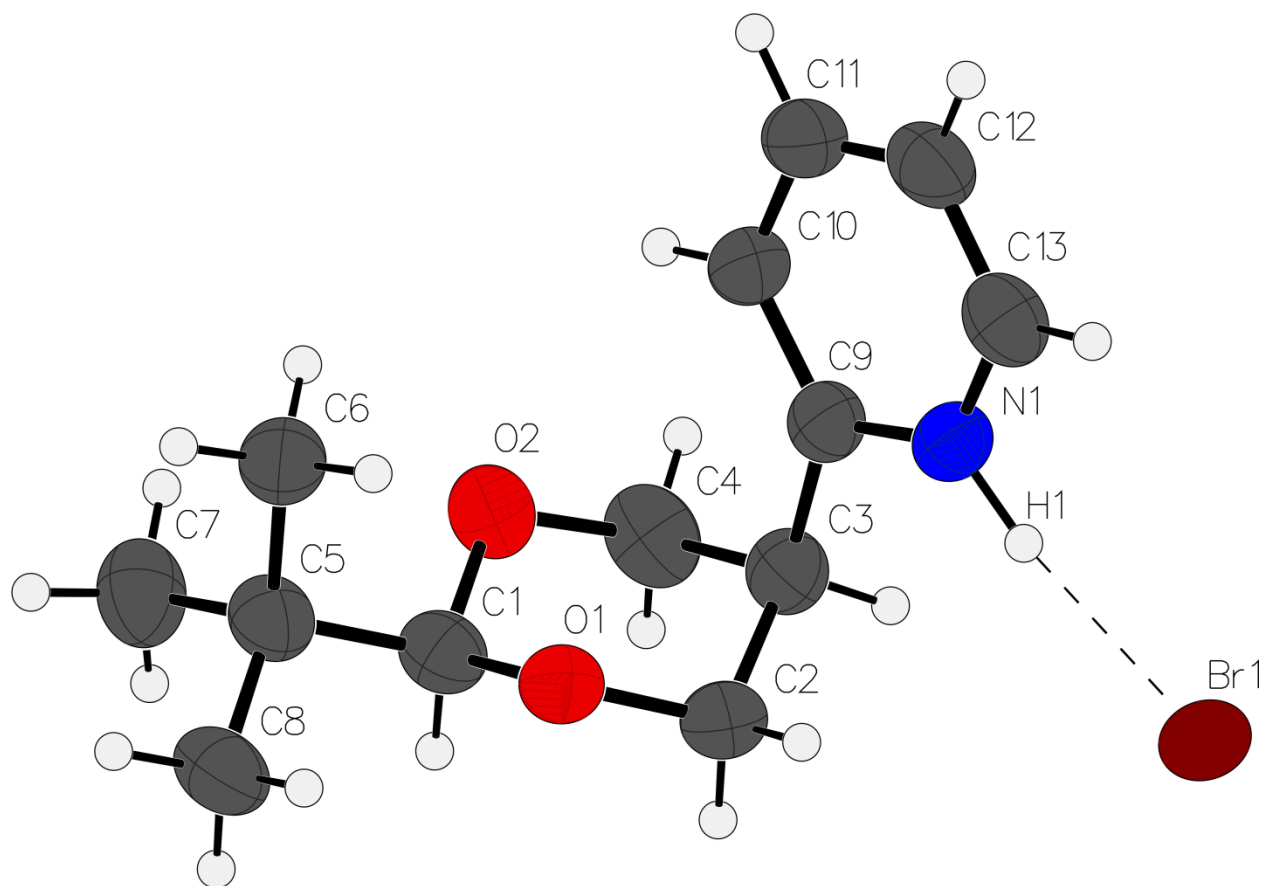
O(2B)-C(1B)-C(10B)-C(13B)	60.9(6)
O(1B)-C(1B)-C(10B)-C(13B)	-177.6(5)

Symmetry transformations used to generate equivalent atoms:

Hydrogen bonds for co-crystal of compounds **17** and **18** [Å and °].

D-H...A	d(D-H)	d(H...A)	d(D...A)	<(DHA)
N(1A)-H(1A)...Br(1A)	0.99(2)	2.33(5)	3.217(4)	148(7)
N(1B)-H(1B)...Br(1B)	1.01(2)	2.24(2)	3.239(4)	173(5)

Symmetry transformations used to generate equivalent atoms:



The complete numbering scheme of compound **17** with 50% thermal ellipsoid probability levels.

The hydrogen atoms are shown as circles for clarity. The dashed line highlights the hydrogen bond between N1 and Br1.

Crystal data and structure refinement for compound **17**.

Identification code	007-16141	
Empirical formula	C ₁₃ H ₂₀ Br N O ₂	
Formula weight	302.21	
Temperature	93(2) K	
Wavelength	1.54178 Å	
Crystal system	Monoclinic	
Space group	P2 ₁ /c	
Unit cell dimensions	a = 12.1445(9) Å	α = 90°.
	b = 9.0910(6) Å	β = 104.447(5)°.
	c = 13.2016(9) Å	γ = 90°.
Volume	1411.44(17) Å ³	
Z	4	
Density (calculated)	1.422 Mg/m ³	
Absorption coefficient	3.900 mm ⁻¹	
F(000)	624	
Crystal size	0.200 x 0.200 x 0.010 mm ³	
Theta range for data collection	3.758 to 67.918°.	
Index ranges	-14 ≤ h ≤ 14, -10 ≤ k ≤ 10, -15 ≤ l ≤ 15	
Reflections collected	37342	
Independent reflections	2537 [R(int) = 0.1854]	
Completeness to theta = 67.679°	99.4 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	1.000 and 0.730	
Refinement method	Full-matrix least-squares on F ²	
Data / restraints / parameters	2537 / 0 / 161	
Goodness-of-fit on F ²	1.052	
Final R indices [I > 2σ(I)]	R1 = 0.0559, wR2 = 0.1527	
R indices (all data)	R1 = 0.0572, wR2 = 0.1555	
Largest diff. peak and hole	1.758 and -0.569 e.Å ⁻³	

Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for compound **17**. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)
Br(1)	9842(1)	5235(1)	1780(1)	50(1)
O(1)	6144(2)	6989(3)	2715(2)	47(1)
O(2)	6453(2)	8153(3)	4330(2)	51(1)
N(1)	8801(2)	4930(3)	3717(2)	44(1)
C(1)	5738(3)	8061(4)	3312(3)	49(1)
C(2)	7254(3)	7334(4)	2613(3)	52(1)
C(3)	8088(3)	7423(4)	3691(3)	48(1)
C(4)	7592(3)	8531(4)	4321(3)	59(1)
C(5)	4540(3)	7644(4)	3373(3)	51(1)
C(6)	4578(3)	6175(4)	3937(3)	54(1)
C(7)	4075(3)	8836(5)	3961(3)	66(1)
C(8)	3780(3)	7529(4)	2258(3)	59(1)
C(9)	8292(2)	5929(3)	4199(2)	43(1)
C(10)	8040(3)	5512(4)	5124(3)	50(1)
C(11)	8323(3)	4105(5)	5512(3)	58(1)
C(12)	8821(3)	3112(4)	4983(3)	56(1)
C(13)	9060(3)	3554(4)	4074(3)	51(1)

Bond lengths [Å] and angles [°] for compound **17**.

O(1)-C(1)	1.417(4)
O(1)-C(2)	1.423(4)
O(2)-C(1)	1.410(4)
O(2)-C(4)	1.428(4)
N(1)-C(9)	1.345(4)
N(1)-C(13)	1.346(4)
N(1)-H(1)	0.98(4)
C(1)-C(5)	1.525(5)
C(1)-H(1A)	1.0000
C(2)-C(3)	1.529(4)
C(2)-H(2A)	0.9900
C(2)-H(2B)	0.9900
C(3)-C(9)	1.508(4)
C(3)-C(4)	1.524(5)
C(3)-H(3)	1.0000
C(4)-H(4A)	0.9900
C(4)-H(4B)	0.9900
C(5)-C(7)	1.521(5)
C(5)-C(6)	1.524(5)
C(5)-C(8)	1.534(5)
C(6)-H(6A)	0.9800
C(6)-H(6B)	0.9800
C(6)-H(6C)	0.9800
C(7)-H(7A)	0.9800
C(7)-H(7B)	0.9800
C(7)-H(7C)	0.9800
C(8)-H(8A)	0.9800
C(8)-H(8B)	0.9800
C(8)-H(8C)	0.9800
C(9)-C(10)	1.383(5)
C(10)-C(11)	1.389(6)
C(10)-H(10)	0.9500
C(11)-C(12)	1.370(5)
C(11)-H(11)	0.9500
C(12)-C(13)	1.365(5)
C(12)-H(12)	0.9500
C(13)-H(13)	0.9500
C(1)-O(1)-C(2)	111.7(3)
C(1)-O(2)-C(4)	112.0(3)
C(9)-N(1)-C(13)	123.9(3)
C(9)-N(1)-H(1)	123.7(19)
C(13)-N(1)-H(1)	112.2(19)
O(2)-C(1)-O(1)	110.7(2)
O(2)-C(1)-C(5)	109.5(3)
O(1)-C(1)-C(5)	109.1(3)
O(2)-C(1)-H(1A)	109.2
O(1)-C(1)-H(1A)	109.2
C(5)-C(1)-H(1A)	109.2
O(1)-C(2)-C(3)	110.3(2)
O(1)-C(2)-H(2A)	109.6
C(3)-C(2)-H(2A)	109.6
O(1)-C(2)-H(2B)	109.6
C(3)-C(2)-H(2B)	109.6

H(2A)-C(2)-H(2B)	108.1
C(9)-C(3)-C(4)	113.3(3)
C(9)-C(3)-C(2)	111.3(3)
C(4)-C(3)-C(2)	106.4(3)
C(9)-C(3)-H(3)	108.6
C(4)-C(3)-H(3)	108.6
C(2)-C(3)-H(3)	108.6
O(2)-C(4)-C(3)	111.2(3)
O(2)-C(4)-H(4A)	109.4
C(3)-C(4)-H(4A)	109.4
O(2)-C(4)-H(4B)	109.4
C(3)-C(4)-H(4B)	109.4
H(4A)-C(4)-H(4B)	108.0
C(7)-C(5)-C(6)	110.2(3)
C(7)-C(5)-C(1)	109.3(3)
C(6)-C(5)-C(1)	109.3(3)
C(7)-C(5)-C(8)	109.1(3)
C(6)-C(5)-C(8)	110.3(3)
C(1)-C(5)-C(8)	108.6(3)
C(5)-C(6)-H(6A)	109.5
C(5)-C(6)-H(6B)	109.5
H(6A)-C(6)-H(6B)	109.5
C(5)-C(6)-H(6C)	109.5
H(6A)-C(6)-H(6C)	109.5
H(6B)-C(6)-H(6C)	109.5
C(5)-C(7)-H(7A)	109.5
C(5)-C(7)-H(7B)	109.5
H(7A)-C(7)-H(7B)	109.5
C(5)-C(7)-H(7C)	109.5
H(7A)-C(7)-H(7C)	109.5
H(7B)-C(7)-H(7C)	109.5
C(5)-C(8)-H(8A)	109.5
C(5)-C(8)-H(8B)	109.5
H(8A)-C(8)-H(8B)	109.5
C(5)-C(8)-H(8C)	109.5
H(8A)-C(8)-H(8C)	109.5
H(8B)-C(8)-H(8C)	109.5
N(1)-C(9)-C(10)	117.5(3)
N(1)-C(9)-C(3)	116.2(3)
C(10)-C(9)-C(3)	126.3(3)
C(9)-C(10)-C(11)	119.3(3)
C(9)-C(10)-H(10)	120.4
C(11)-C(10)-H(10)	120.4
C(12)-C(11)-C(10)	121.3(3)
C(12)-C(11)-H(11)	119.4
C(10)-C(11)-H(11)	119.4
C(13)-C(12)-C(11)	118.2(3)
C(13)-C(12)-H(12)	120.9
C(11)-C(12)-H(12)	120.9
N(1)-C(13)-C(12)	119.9(3)
N(1)-C(13)-H(13)	120.0
C(12)-C(13)-H(13)	120.0

Symmetry transformations used to generate equivalent atoms:

Anisotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for compound **17**. The anisotropic displacement factor exponent takes the form: $-2\pi^2 [h^2 a^{*2} U^{11} + \dots + 2 h k a^* b^* U^{12}]$

	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
Br(1)	64(1)	45(1)	43(1)	-1(1)	19(1)	3(1)
O(1)	48(1)	50(1)	42(1)	2(1)	10(1)	0(1)
O(2)	49(1)	51(1)	52(1)	-8(1)	8(1)	1(1)
N(1)	43(2)	49(1)	40(2)	-1(1)	12(1)	-4(1)
C(1)	50(2)	43(2)	50(2)	3(1)	9(1)	2(1)
C(2)	52(2)	58(2)	49(2)	13(2)	15(1)	2(2)
C(3)	43(2)	47(2)	55(2)	4(1)	13(1)	-4(1)
C(4)	53(2)	49(2)	69(2)	-8(2)	4(2)	-6(1)
C(5)	48(2)	42(2)	61(2)	8(2)	13(1)	2(1)
C(6)	54(2)	47(2)	63(2)	10(2)	20(2)	3(1)
C(7)	60(2)	53(2)	89(3)	2(2)	26(2)	6(2)
C(8)	50(2)	53(2)	68(2)	16(2)	2(2)	-1(2)
C(9)	38(1)	49(2)	41(2)	-2(1)	8(1)	-4(1)
C(10)	46(2)	65(2)	40(2)	5(2)	12(1)	3(2)
C(11)	44(2)	75(3)	53(2)	20(2)	10(1)	-1(2)
C(12)	41(2)	57(2)	63(2)	15(2)	2(1)	-3(1)
C(13)	44(2)	47(2)	58(2)	-3(2)	4(1)	-1(1)

Hydrogen coordinates ($\times 10^4$) and isotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for compound **17**.

	x	y	z	U(eq)
H(1)	9090(30)	5150(30)	3100(30)	44(9)
H(1A)	5715	9039	2961	58
H(2A)	7238	8288	2247	63
H(2B)	7509	6569	2189	63
H(3)	8829	7813	3604	58
H(4A)	8069	8561	5048	71
H(4B)	7601	9523	4014	71
H(6A)	4954	5440	3595	80
H(6B)	3802	5852	3911	80
H(6C)	5004	6288	4668	80
H(7A)	4480	8808	4702	99
H(7B)	3262	8668	3890	99
H(7C)	4183	9801	3668	99
H(8A)	3765	8478	1903	89
H(8B)	3006	7262	2286	89
H(8C)	4082	6773	1872	89
H(10)	7676	6180	5489	60
H(11)	8170	3825	6156	69
H(12)	8994	2142	5243	67
H(13)	9410	2892	3693	62

Torsion angles [°] for compound **17**.

C(4)-O(2)-C(1)-O(1)	59.2(3)
C(4)-O(2)-C(1)-C(5)	179.6(3)
C(2)-O(1)-C(1)-O(2)	-60.6(3)
C(2)-O(1)-C(1)-C(5)	178.8(2)
C(1)-O(1)-C(2)-C(3)	59.7(3)
O(1)-C(2)-C(3)-C(9)	69.0(3)
O(1)-C(2)-C(3)-C(4)	-54.9(3)
C(1)-O(2)-C(4)-C(3)	-57.7(4)
C(9)-C(3)-C(4)-O(2)	-68.6(4)
C(2)-C(3)-C(4)-O(2)	54.0(4)
O(2)-C(1)-C(5)-C(7)	61.8(4)
O(1)-C(1)-C(5)-C(7)	-176.9(3)
O(2)-C(1)-C(5)-C(6)	-58.9(3)
O(1)-C(1)-C(5)-C(6)	62.5(4)
O(2)-C(1)-C(5)-C(8)	-179.2(3)
O(1)-C(1)-C(5)-C(8)	-57.9(3)
C(13)-N(1)-C(9)-C(10)	1.0(4)
C(13)-N(1)-C(9)-C(3)	178.9(3)
C(4)-C(3)-C(9)-N(1)	-175.6(3)
C(2)-C(3)-C(9)-N(1)	64.5(3)
C(4)-C(3)-C(9)-C(10)	2.1(4)
C(2)-C(3)-C(9)-C(10)	-117.8(3)
N(1)-C(9)-C(10)-C(11)	0.3(5)
C(3)-C(9)-C(10)-C(11)	-177.4(3)
C(9)-C(10)-C(11)-C(12)	-1.7(5)
C(10)-C(11)-C(12)-C(13)	1.8(5)
C(9)-N(1)-C(13)-C(12)	-1.0(5)
C(11)-C(12)-C(13)-N(1)	-0.4(5)

Symmetry transformations used to generate equivalent atoms:

Hydrogen bonds for compound **17** [Å and °].

D-H...A	d(D-H)	d(H...A)	d(D...A)	<(DHA)
N(1)-H(1)...Br(1)	0.98(4)	2.17(5)	3.136(3)	170(3)

Symmetry transformations used to generate equivalent atoms:

References Chapter II Section 2.3

- ¹ Bailey, W. F.; Lambert, K. M.; Stempel, Z. D.; Wiberg, K. B.; Mercado, B. Q. *J. Org. Chem.* **2016**, *81*, 12116–12127.
- ² (a) Rathman, T. L.; Schwindeman, J. A. *Org. Process Res. Dev.* **2014**, *18*, 1192. (b) Shriver, D. F.; Drezdon, M. A. *The Manipulation of Air-Sensitive Compounds*, 2nd ed.; Wiley: New York, **1986**.
- ³ Watson, S. C.; Eastham, J. F. *J. Organomet. Chem.* **1967**, *9*, 165.
- ⁴ Zimmermann, B.; Dzik, W. I.; Himmler, T.; Goossen, L. J. *J. Org. Chem.* **2011**, *76*, 8107.
- ⁵ Xu, Y.; McLaughlin, M.; Chen, C.; Reamer, R. A.; Dormer, P. G.; Davies, I. W. *J. Org. Chem.* **2009**, *74*, 5100.
- ⁶ Katz, C. E.; Aubé, J. *J. Am. Chem. Soc.* **2003**, *125*, 13948.
- ⁷ Brown, H. C.; Kim, C. J. *J. Am. Chem. Soc.* **1968**, *90*, 2082.
- ⁸ Davis, O. A.; Croft, R. A.; Bull, J. A. *J. Chem. Soc., Chem. Commun.* **2015**, *51*, 15446.
- ⁹ Rosenkrantz, B. E.; Citarel, L.; Heinsohn, G. E.; Becker, E. L. *J. Chem. Eng. Data* **1963**, *8*, 237.
- ¹⁰ Mattiello, L.; Rampazzo, L.; Sotgiu, G. *J. Chem. Res., Miniprint* **1992**, *10*, 2732.
- ¹¹ Ghoneim, O. M.; Legere, J. A.; Golbraikh, A.; Tropsha, A.; Booth, R. G. *Bioorgan. Med. Chem.* **2006**, *14*, 6640.
- ¹² Enoua, C. G.; Uray, G.; Stadlbauer, W. *J. Heterocyclic Chem.* **2012**, *49*, 1415.
- ¹³ Ríos-Lombardía, N.; Busto, E.; García-Urdiales, E.; Gotor-Fernández, V.; Gotor, V. *J. Org. Chem.* **2009**, *74*, 2571.
- ¹⁴ Semmes, J. G.; Bevans, S. L.; Mullins, C. H.; Shaughnessy, K. H. *Tetrahedron Lett.* **2015**, *56*, 3447.
- ¹⁵ Lauer, W. M.; Hansen, L. I. *J. Am. Chem. Soc.* **1939**, *61*, 3039.
- ¹⁶ Levene, P. A.; Meyer, G. M. *Org. Synth.* **1936**, *16*, 33.
- ¹⁷ Beringer, F. M.; Forgione, P. S. *Tetrahedron* **1963**, *19*, 739.
- ¹⁸ Endo, Y.; Baeckvall, J. E. *Chem. Eur. J.* **2011**, *17*, 12596.
- ¹⁹ Eliel, E. L.; Knoeber, M. C. *J. Am. Chem. Soc.* **1968**, *90*, 3444.
- ²⁰ Choi, Y. N.; Kucharczyk, N.; Sofia, R. D. *Tetrahedron* **1986**, *42*, 6399.
- ²¹ Guanti, G.; Narisano, E.; Riva, R. *Tetrahedron: Asymmetry* **1997**, *8*, 2175.
- ²² Lipp, A.; Richard, J. *Ber. Dtsch. Chem. Ges.* **1904**, *37*, 737.
- ²³ Cioffi, E. A.; Bailey, W. F. *Tetrahedron Lett.* **1998**, *39*, 2679.
- ²⁴ Sheldrick, G. *Acta Cryst., Section A* **2008**, *64*, 112.
- ²⁵ These data can be obtained free of charge from The Cambridge Crystallographic Data Center via www.ccdc.cam.ac.uk/data_request/cif.
- ²⁶ Gaussian 09, Revision C.01 Frisch, M. J.; Trucks, G. W.; Schlegel, H. B.; Scuseria, G. E.; Robb, M. A.; Cheeseman, J. R.; Scalmani, G.; Barone, V.; Mennucci, B.; Petersson, G. A.; Nakatsuji, H.; Caricato, M.; Li, X.; Hratchian, H. P.; Izmaylov, A. F.; Bloino, J.; Zheng, G.; Sonnenberg, J. L.; Hada, M.; Ehara, M.; Toyota, K.; Fukuda, R.; Hasegawa, J.; Ishida, M.; Nakajima, T.; Honda, Y.; Kitao, O.; Nakai, H.; Vreven, T.; Montgomery, J. A., Jr.; Peralta, J. E.; Ogliaro, F.; Bearpark, M.; Heyd, J. J.; Brothers, E.; Kudin, K. N.; Staroverov, V. N.; Kobayashi, R.; Normand, J.; Raghavachari, K.; Rendell, A.; Burant, J. C.; Iyengar, S. S.; Tomasi, J.; Cossi, M.; Rega, N.; Millam, N. J.; Klene, M.; Knox, J. E.; Cross, J. B.; Bakken, V.; Adamo, C.; Jaramillo, J.; Gomperts, R.; Stratmann, R. E.; Yazyev, O.; Austin, A. J.; Cammi, R.; Pomelli, C.; Ochterski, J. W.; Martin, R. L.; Morokuma, K.; Zakrzewski, V. G.; Voth, G. A.; Salvador, P.; Dannenberg, J. J.; Dapprich, S.; Daniels, A. D.; Farkas, Ö.; Foresman, J. B.; Ortiz, J. V.; Cioslowski, J.; Fox, D. J.; Gaussian, Inc. Wallingford, CT 2009.
- ²⁷ Legault, C. Y CYLview 1.0b; Université de Sherbrook: Sherbrook, QC, Canada, 2009. <http://www.cylview.org>



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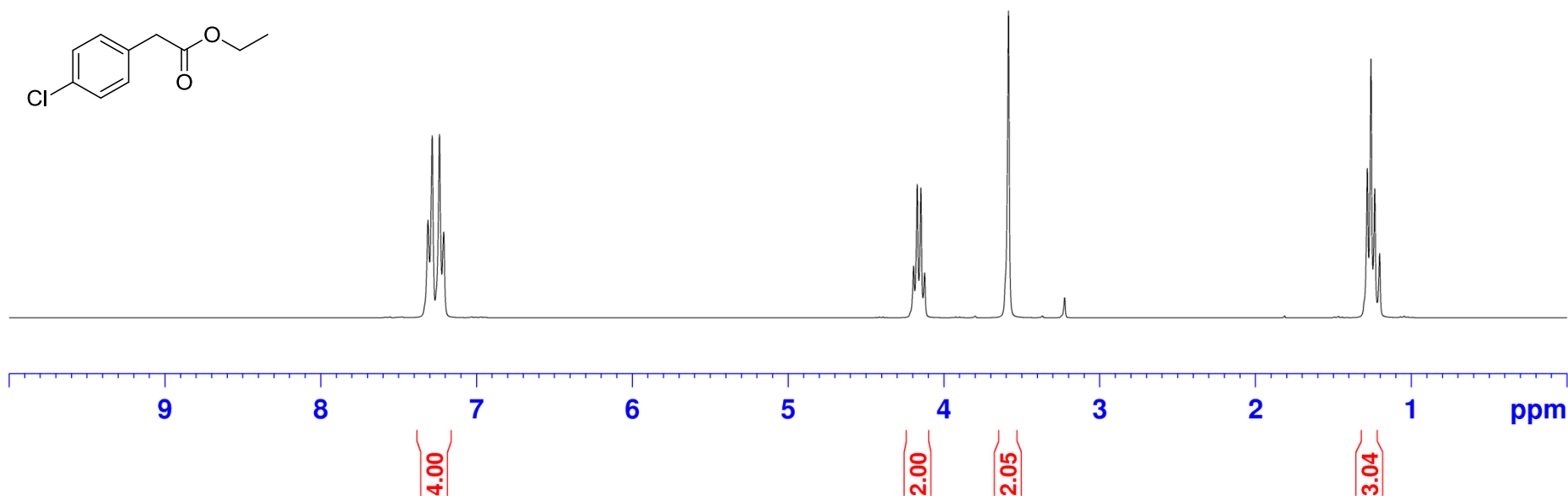
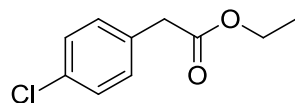
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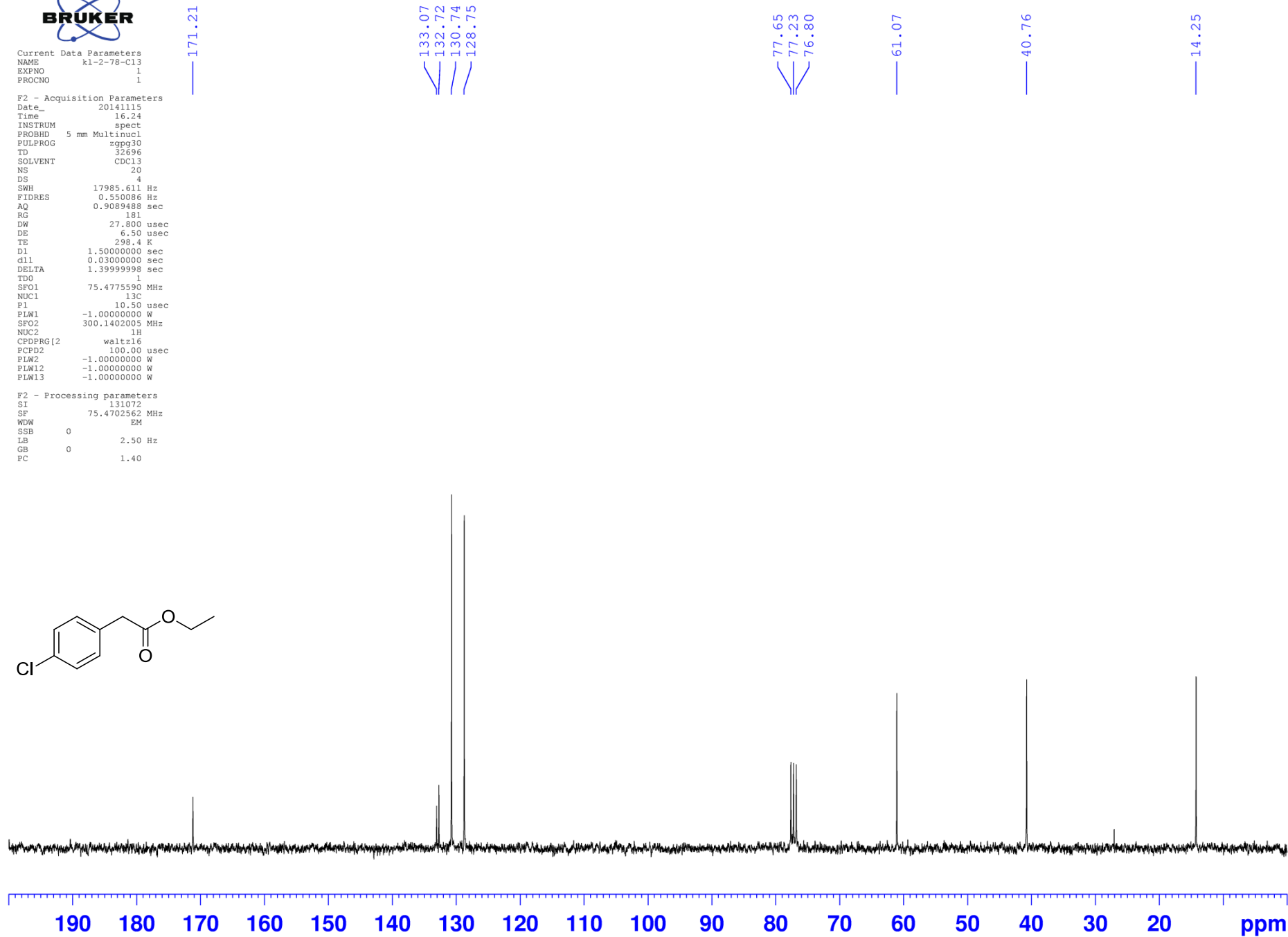
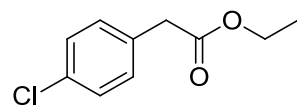




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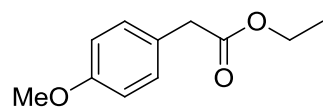


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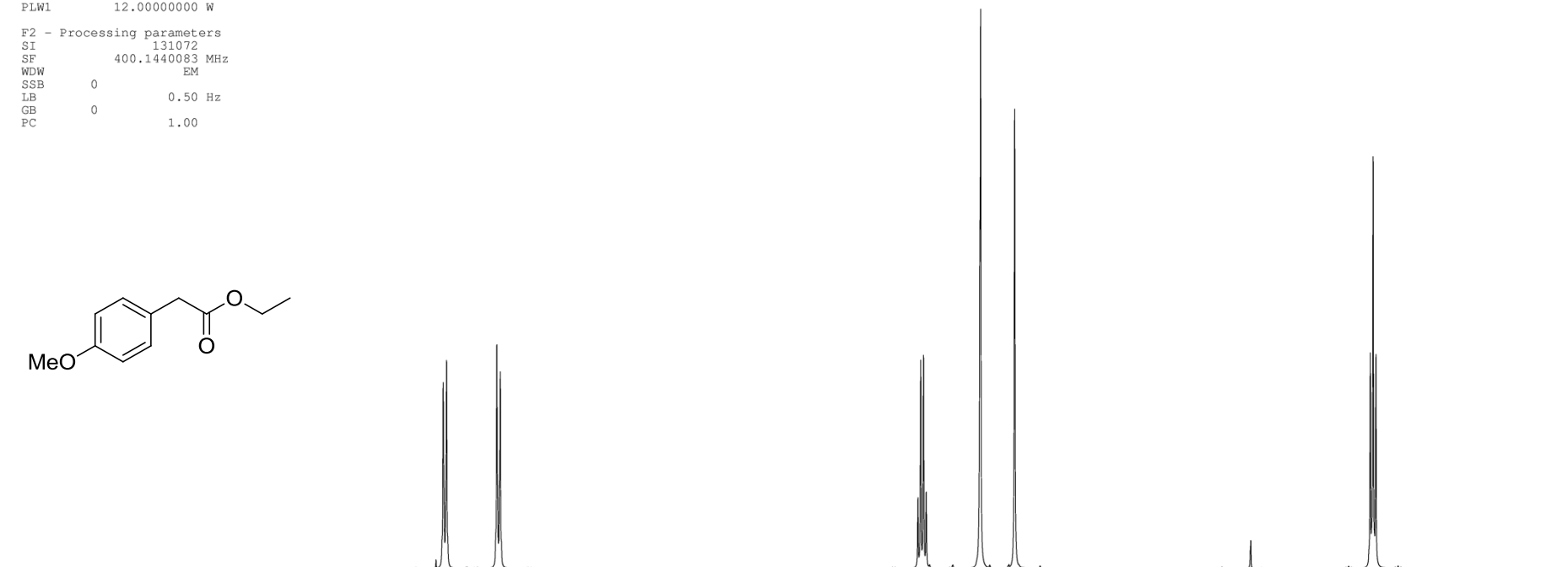
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4.11
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1.24
1.23



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8

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4

3

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ppm

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2.01

3.09

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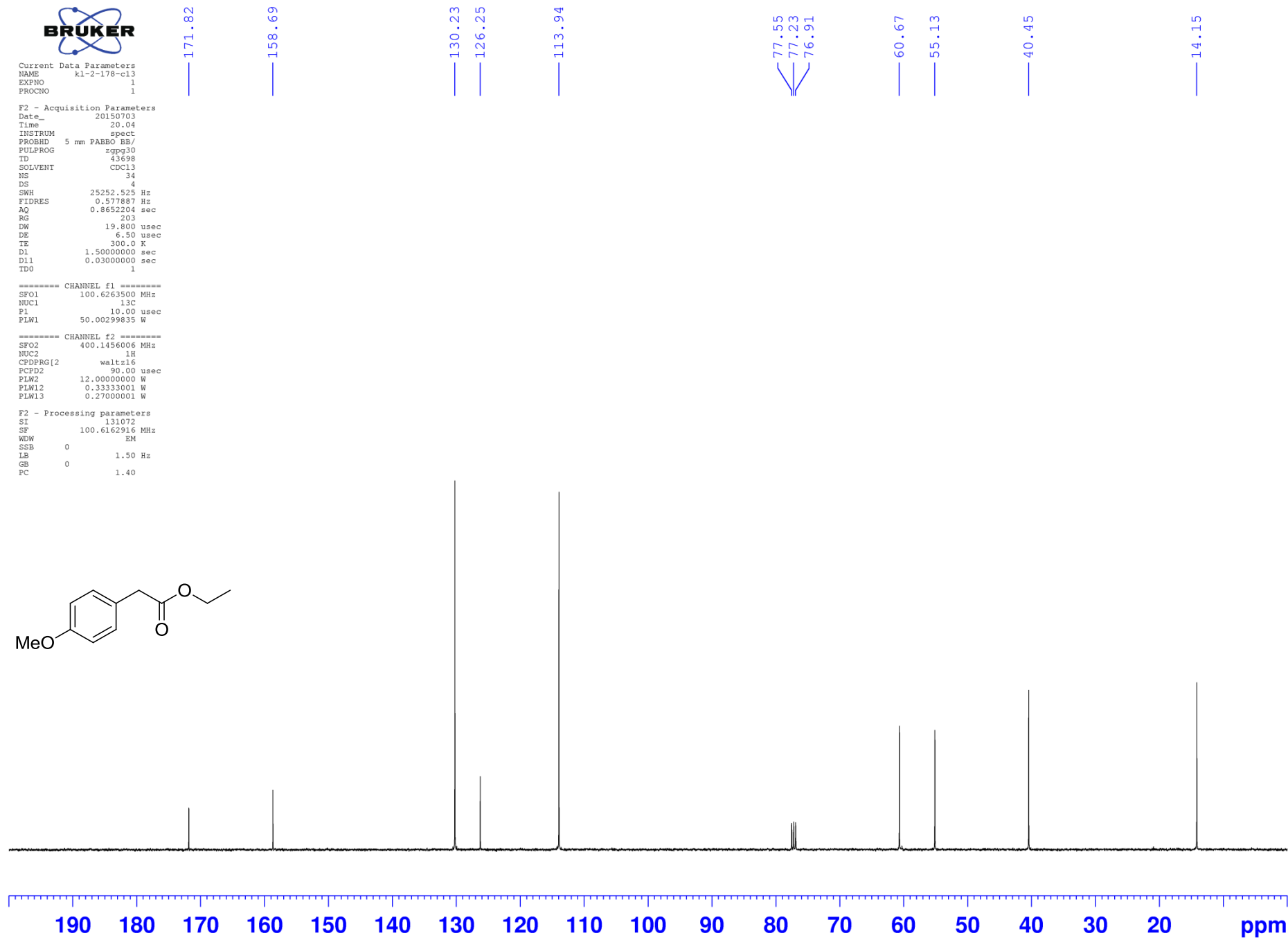
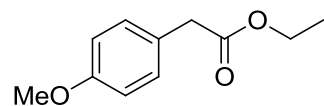
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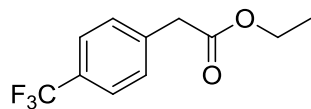


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SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 45.2
DW 62.400 usec
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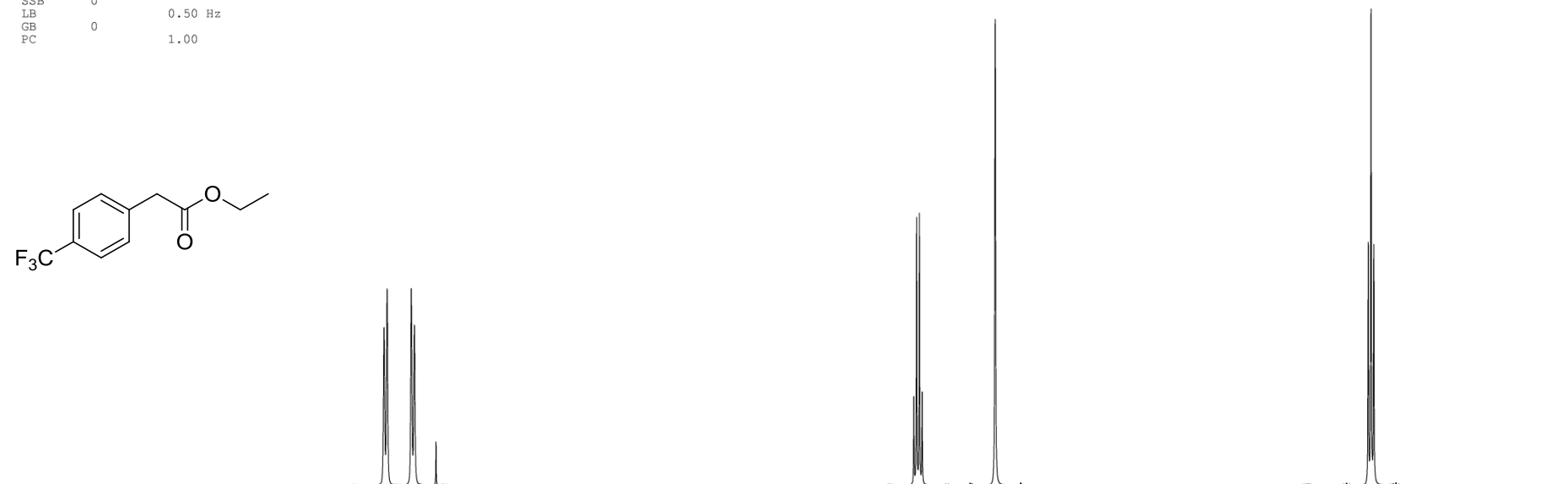
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4.16
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1.26
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8

7

6

5

4

3

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ppm

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2.02

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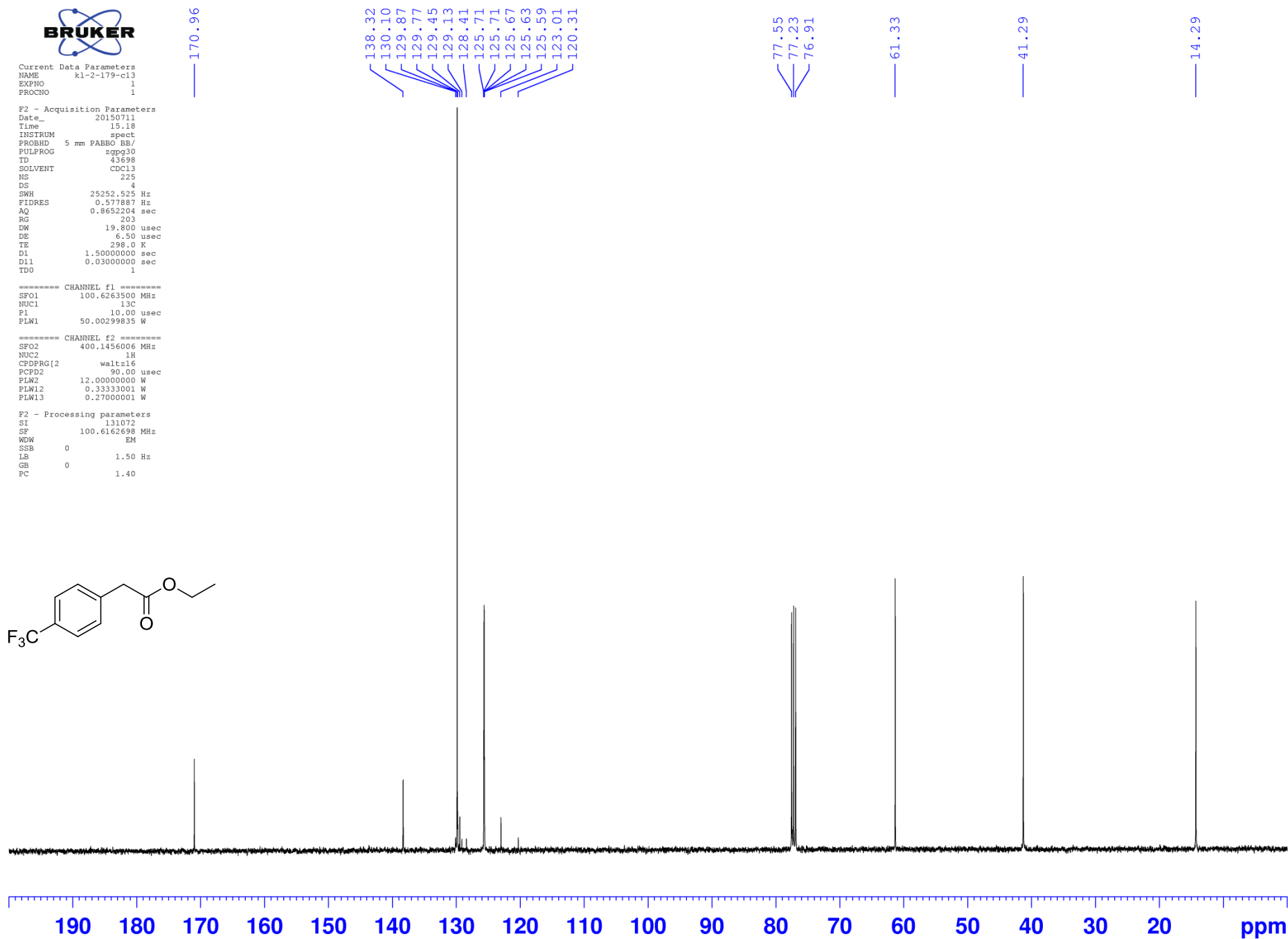
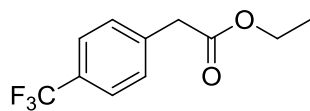
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RG 203
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DE 6.50 usec
TE 298.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

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PCPD2 90.00 usec
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PLW12 0.33333001 W
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PC 1.40



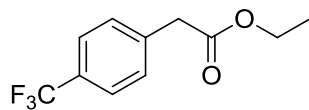


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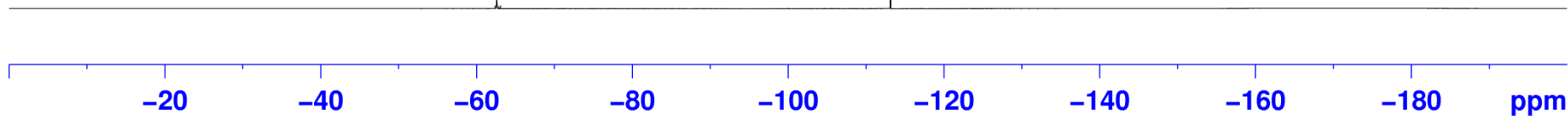
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-113.15
-113.17
-113.18
-113.19
-113.20



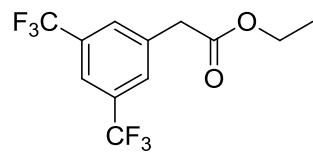


Current Data Parameters
NAME kl-2-180-h1
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150704
Time 0.57
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 25.4
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440094 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00

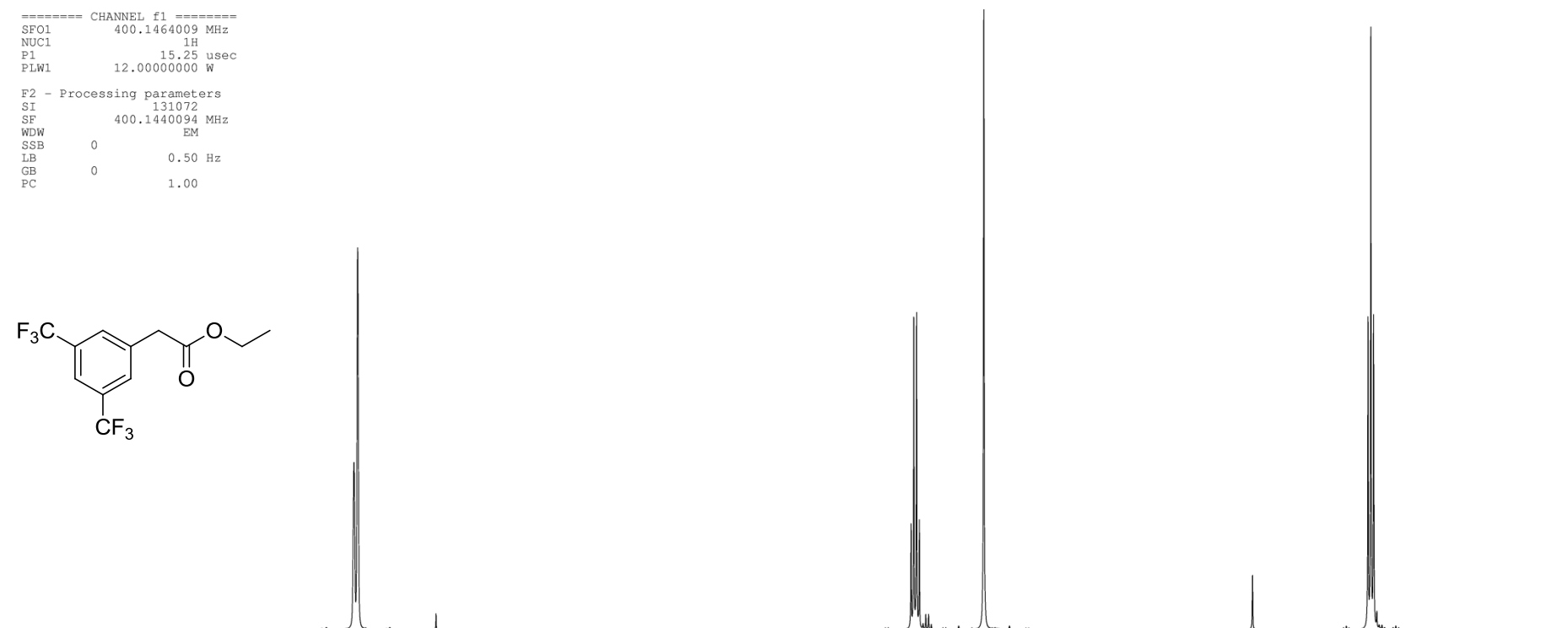


7.79
7.76

7.26

4.21
4.19
4.18
4.16
3.74

1.28
1.26
1.24



9

8

7

6

5

4

3

2

1

ppm

2.94

1.95

2.00

3.03



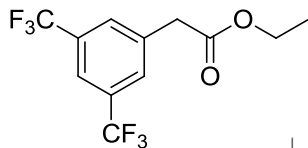
Current Data Parameters
NAME kl-2-180-cl3
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150704
Time 1.07
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 84
DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
AQ 0.8652204 sec
RG 203
DW 19.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CFDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162628 MHz
WDW EM
SSB 0
LB 1.50 Hz
GB 0
PC 1.40



170.18

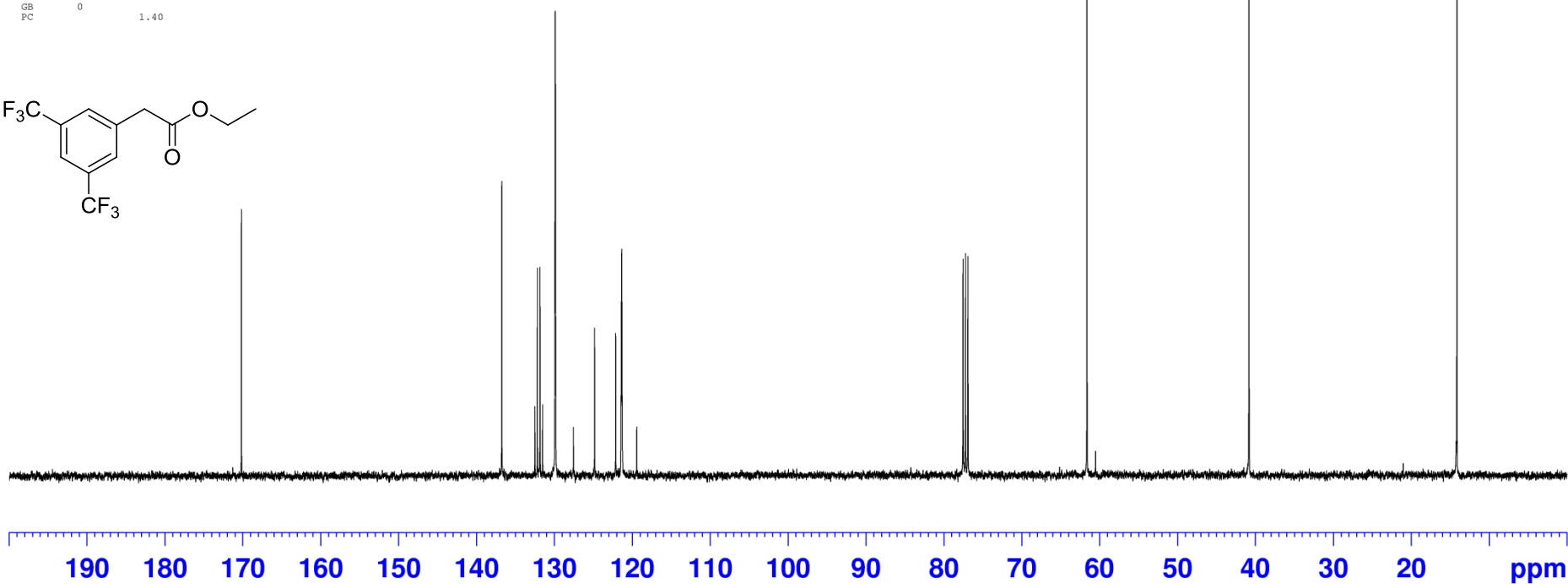
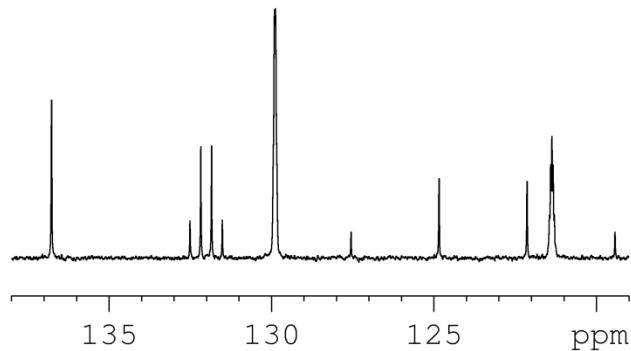
136.76
132.51
132.18
131.85
131.52
129.95
129.91
129.88
129.84
127.55
124.84
122.14
121.48
121.44
121.41
121.37
121.33
121.29
121.26
119.43

77.55
77.23
76.91

61.63

40.83

14.15





Current Data Parameters
NAME k1-2-180-F19
EXPNO 1
PROCNO 1

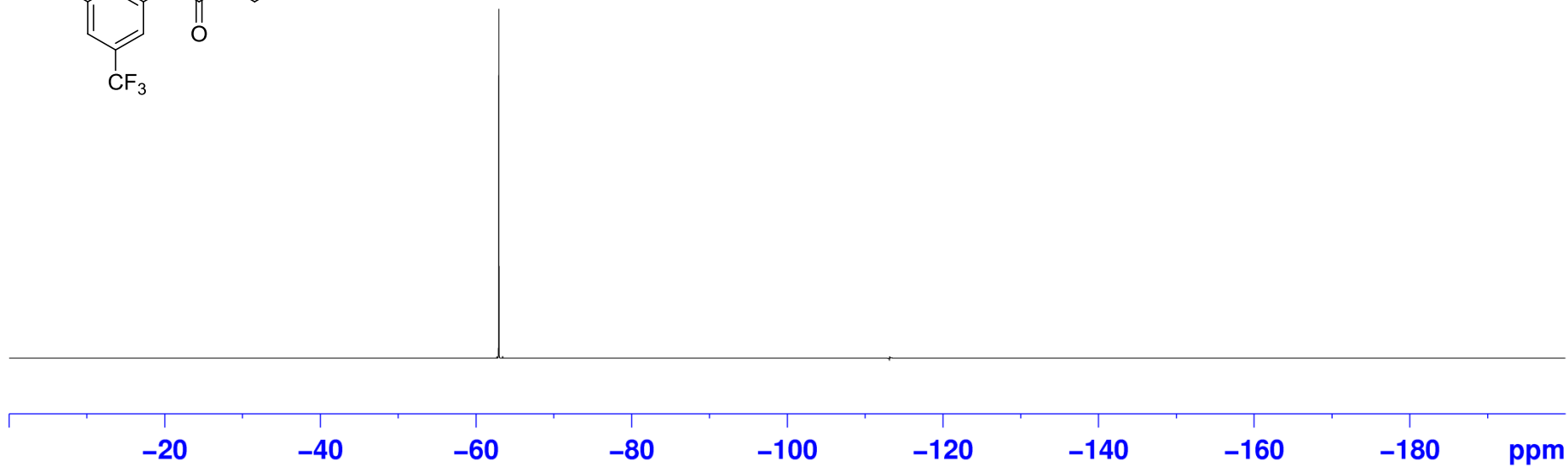
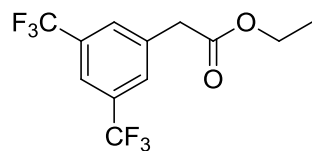
F2 - Acquisition Parameters
Date_ 20150704
Time 1.12
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 131072
SOLVENT CDCl3
NS 8
DS 4
SWH 89285.711 Hz
FIDRES 0.681196 Hz
AQ 0.7340032 sec
RG 90.5
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 1.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 376.4738882 MHz
NUC1 19F
P1 14.00 usec
PLW1 18.00000000 W

F2 - Processing parameters
SI 65536
SF 376.5114633 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

— -62.96

— -113.15



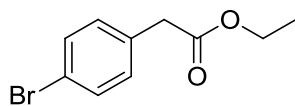


Current Data Parameters
NAME kl-2-184
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150712
Time 23.36
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 22.6
DW 62.400 usec
DE 6.50 usec
TE 298.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

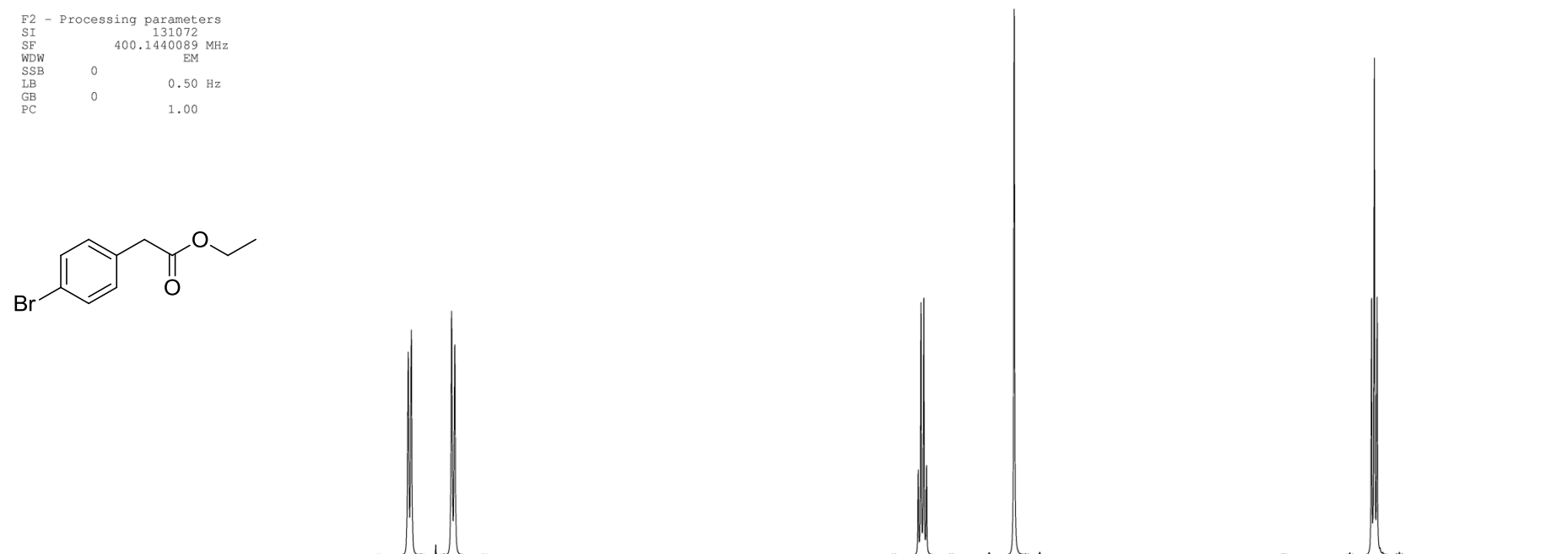
F2 - Processing parameters
SI 131072
SF 400.1440089 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00



7.44
7.42
7.26
7.16
7.14

4.16
4.15
4.13
4.11
3.55

1.25
1.24
1.22



9

8

7

6

5

4

3

2

1

ppm

2.00
2.02

2.03
2.03

3.09



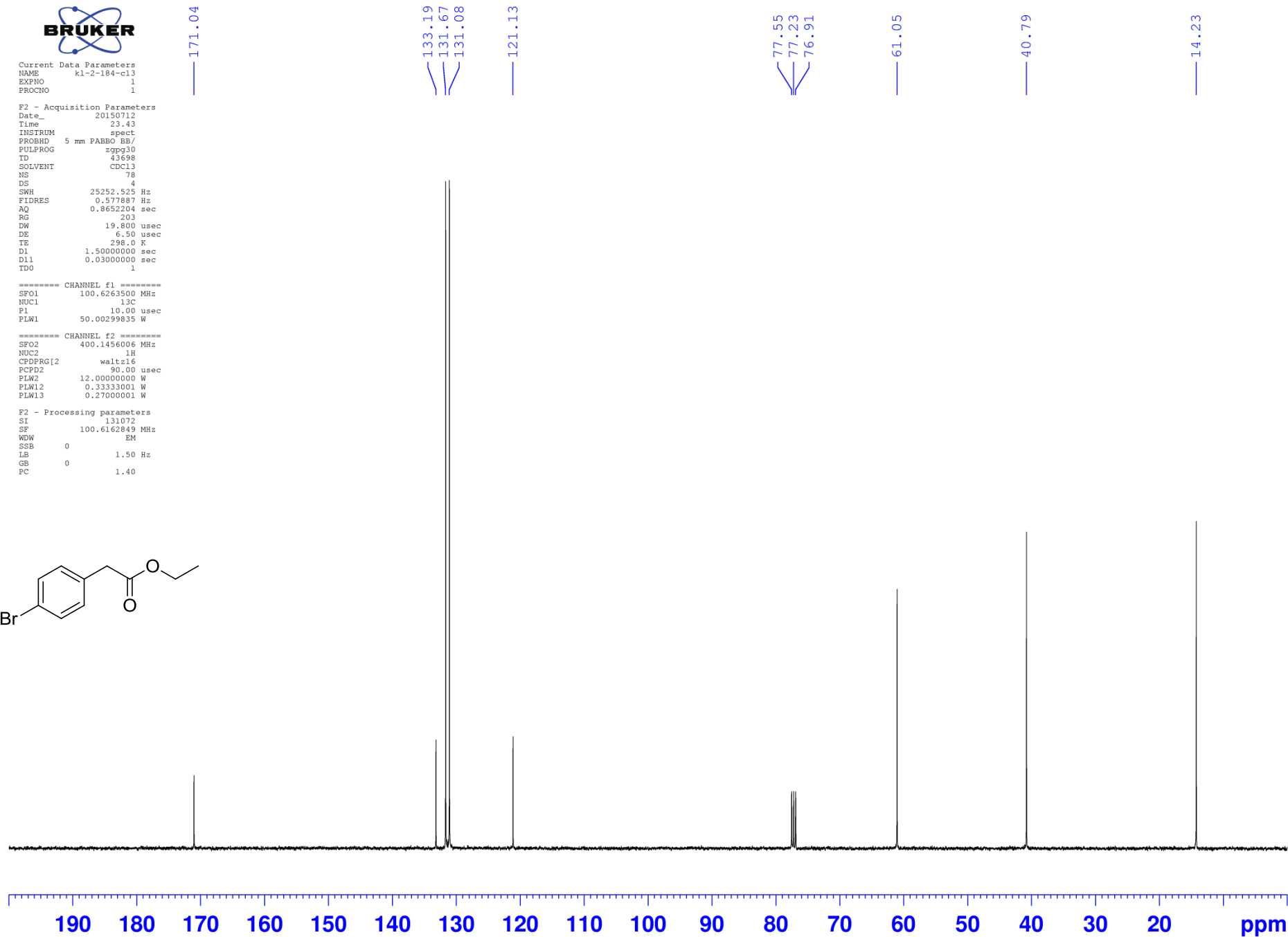
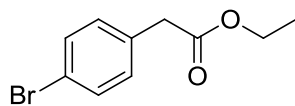
Current Data Parameters
NAME kl-2-184-cl3
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150712
Time 23.43
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 78
DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
AQ 0.8652204 sec
RG 203
DW 19.800 usec
DE 6.50 usec
TE 298.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162849 MHz
WDW EM
SSB 0
LB 1.50 Hz
GB 0
PC 1.40



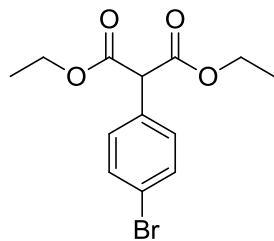


Current Data Parameters
NAME k1-2-187-1H
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150805
Time 16.00
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 28.5
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

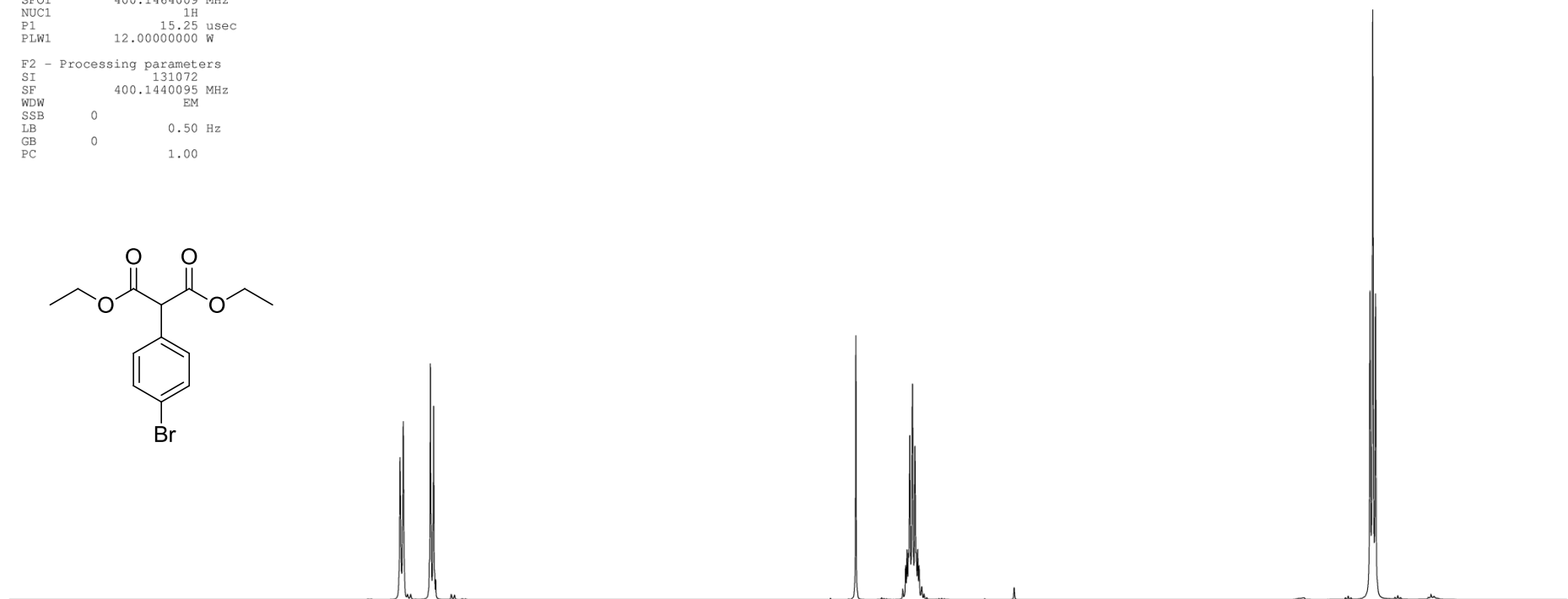
F2 - Processing parameters
SI 131072
SF 400.1440095 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00



7.49
7.47
7.29
7.27
7.26

4.57
4.26
4.25
4.24
4.23
4.22
4.20
4.19
4.18
4.17
4.16
4.14

1.27
1.25
1.23



9

8

7

6

5

4

3

2

1

ppm

2.00
2.02

1.00
4.02

6.08



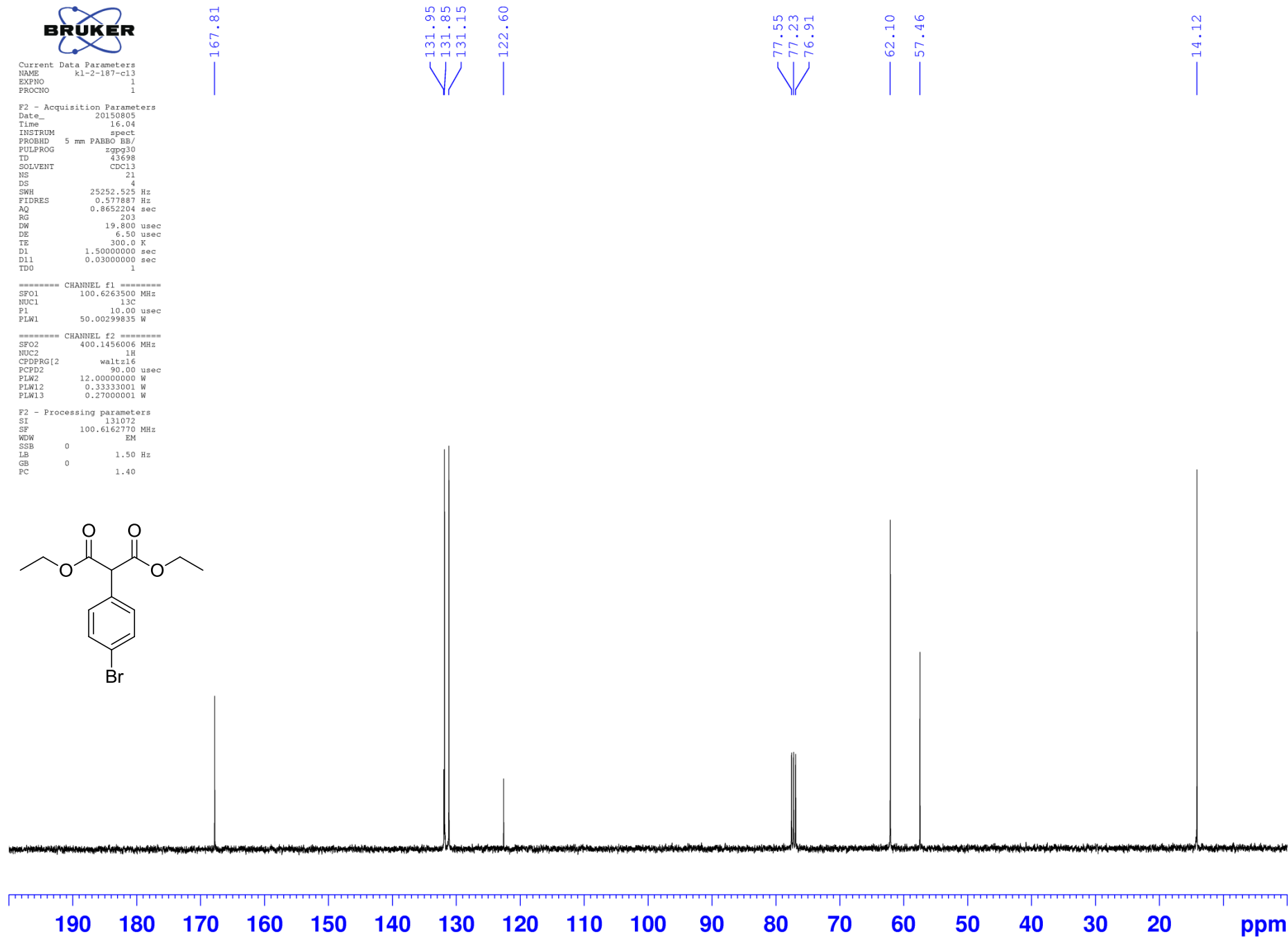
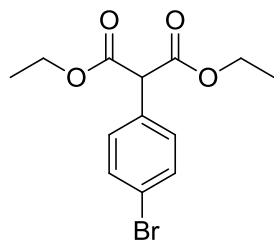
Current Data Parameters
NAME kl-2-187-cl3
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150805
Time 16.04
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 21
DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
AQ 0.8652204 sec
RG 203
DW 19.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162770 MHz
WDW EM
SSB 0
LB 1.50 Hz
GB 0
PC 1.40



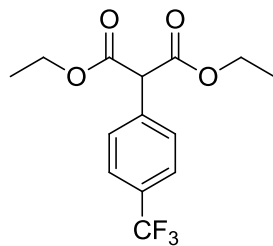


Current Data Parameters
NAME k1-2-185-H1
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150714
Time 13.30
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 32
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

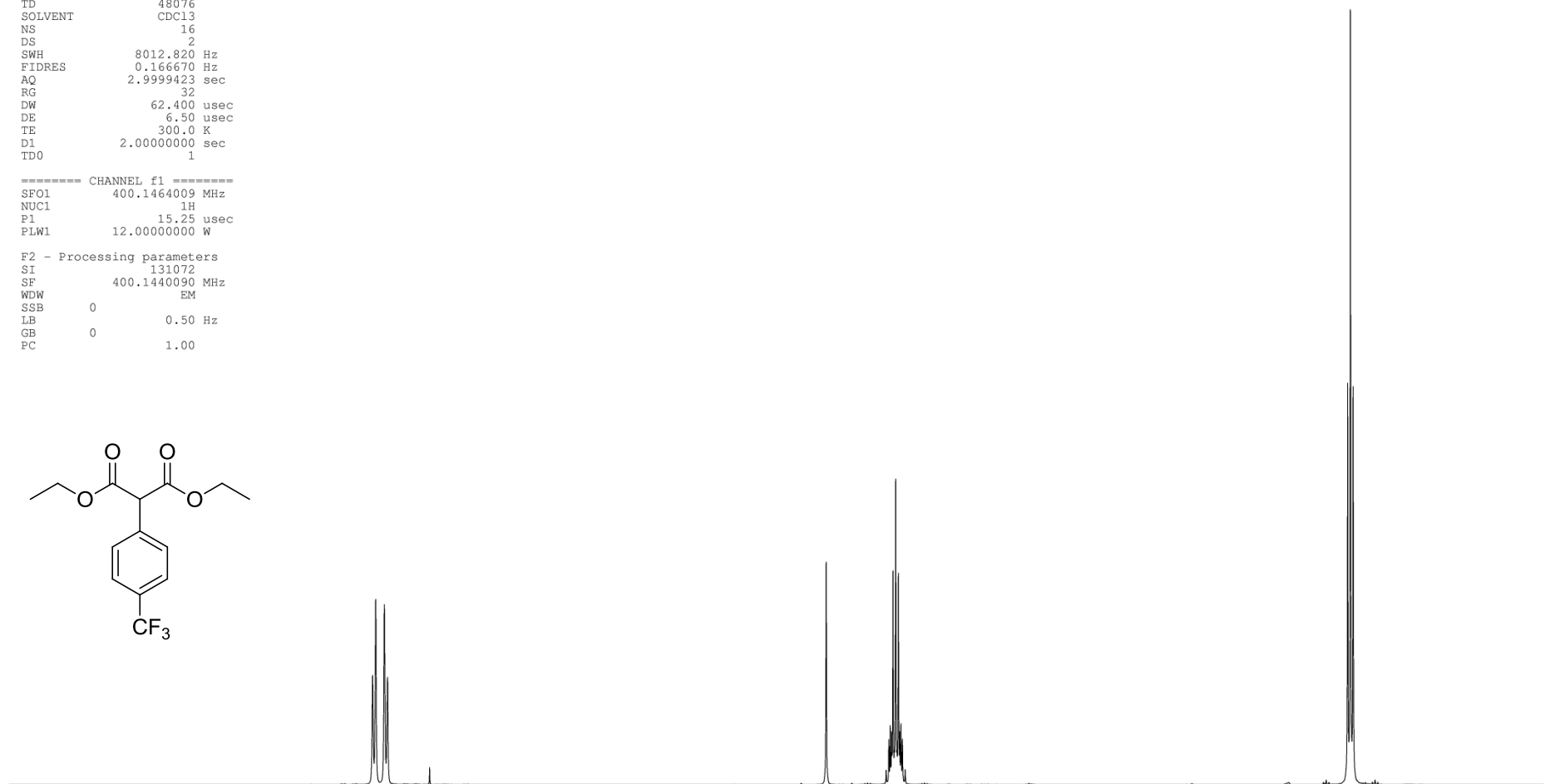
F2 - Processing parameters
SI 131072
SF 400.1440090 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00



7.63
7.61
7.55
7.53
7.26

4.68
4.29
4.27
4.26
4.25
4.24
4.23
4.22
4.22
4.21
4.20
4.19
4.18
4.16

1.28
1.26
1.24



9

8

7

6

5

4

3

2

1

ppm

1.98
2.00

0.97

4.04

6.01



Current Data Parameters
NAME kl-2-185-cl3
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150714
Time 13.40
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 143
DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
AQ 0.8652204 sec
RG 203
DW 19.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CFDPRG[2] waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162708 MHz
WDW EM
SSB 0
LB 1.50 Hz
GB 0
PC 1.40

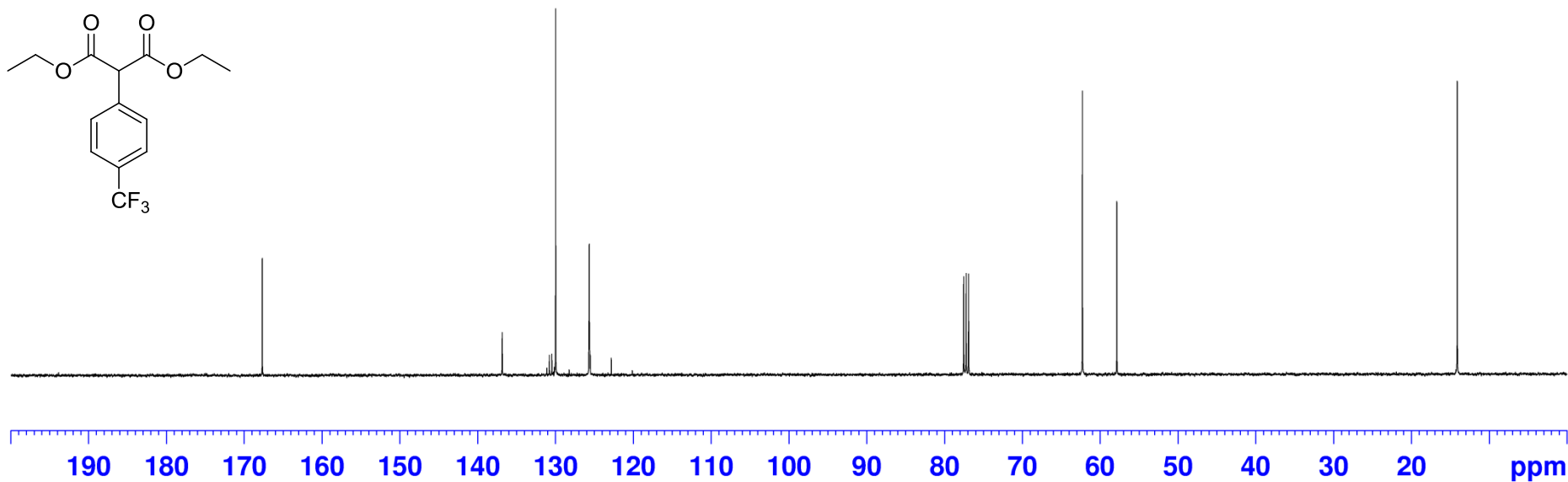
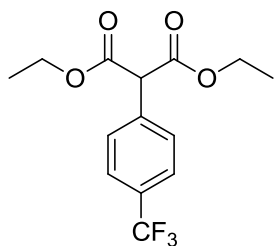
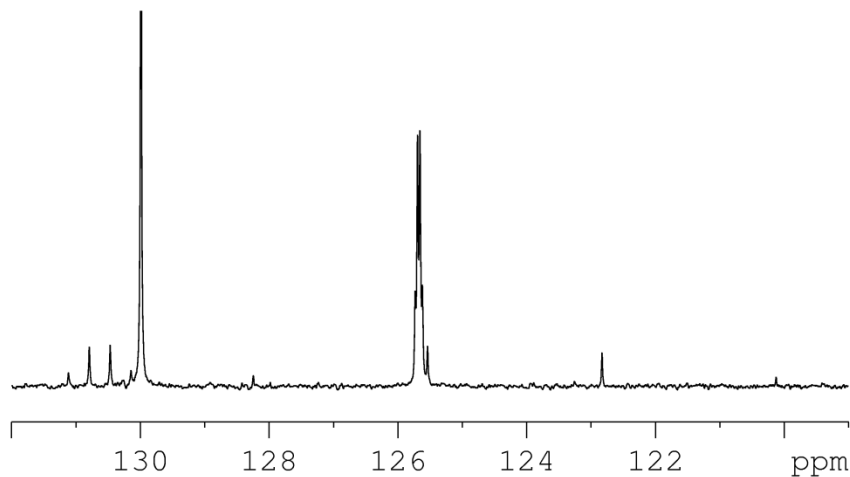
167.66

136.86
131.11
130.79
130.47
130.14
129.99
128.24
125.73
125.69
125.65
125.62
125.54
122.83
120.13

77.55
77.23
76.91

62.28
57.86

14.11



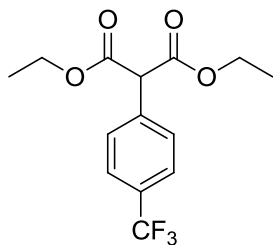


Current Data Parameters
NAME k1-2-185-f19
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150714
Time 13.46
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 131072
SOLVENT CDCl3
NS 8
DS 4
SWH 89285.711 Hz
FIDRES 0.681196 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 1.0000000 sec
TD0 1

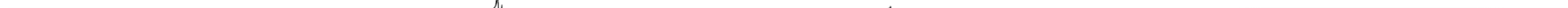
===== CHANNEL f1 =====
SFO1 376.4738882 MHz
NUC1 19F
P1 14.00 usec
PLW1 18.00000000 W

F2 - Processing parameters
SI 65536
SF 376.5115310 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



— -62.76

— -113.15



-20

-40

-60

-80

-100

-120

-140

-160

-180

ppm

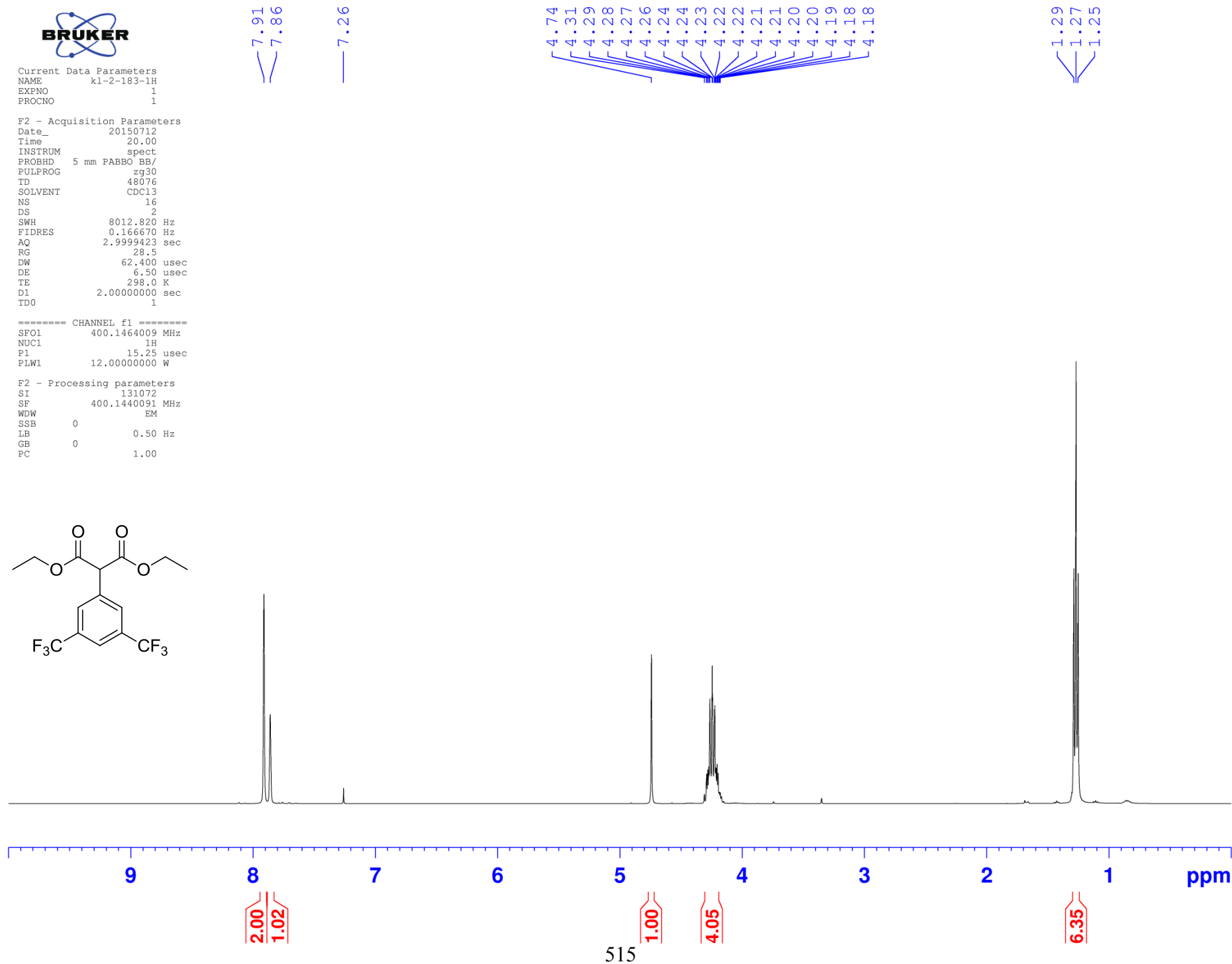
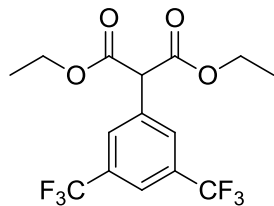


Current Data Parameters
NAME kl-2-183-1H
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150712
Time 20.00
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 28.5
DW 62.400 usec
DE 6.50 usec
TE 298.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440091 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00





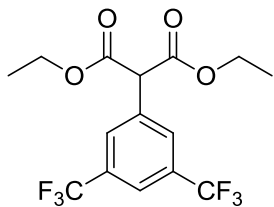
Current Data Parameters
NAME kl-2-183-13C
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150712
Time 20.08
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 77
DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
AQ 0.8652204 sec
RG 203
DW 19.800 usec
DE 6.50 usec
TE 298.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162662 MHz
WDW EM
SSB 0
LB 1.50 Hz
GB 0
PC 1.40



167.04

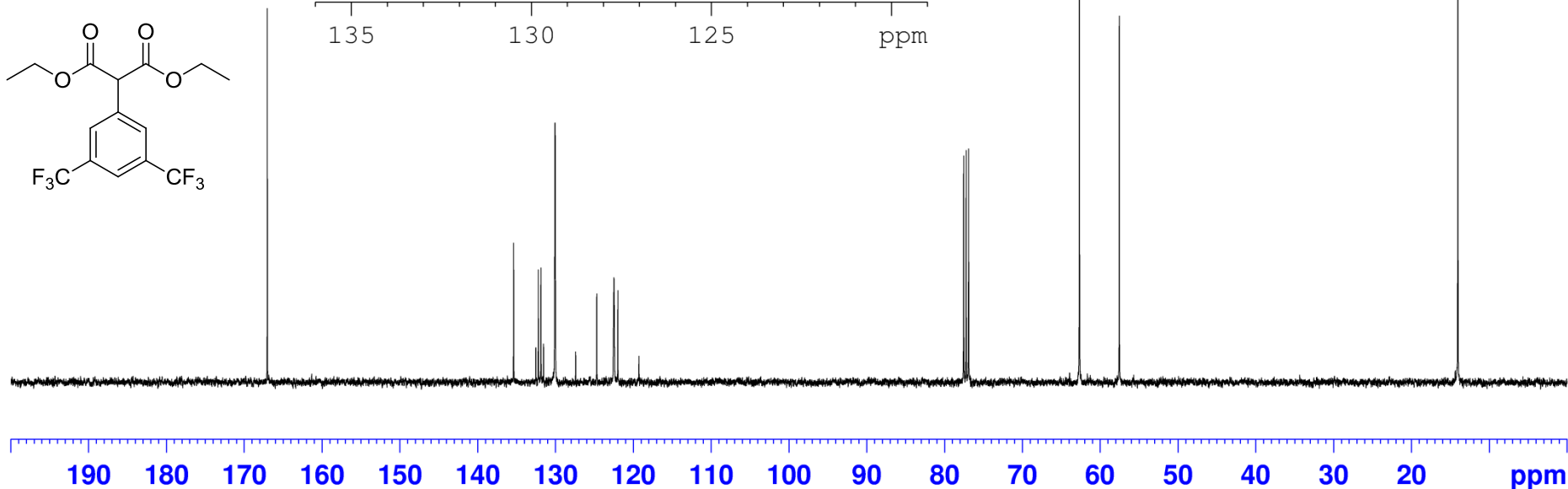
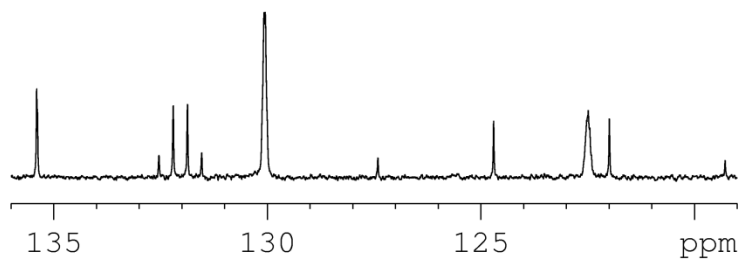
135.39
132.54
132.20
131.87
131.53
130.11
130.07
130.05
130.01
127.41
124.70
122.59
122.56
122.54
122.52
122.50
122.48
122.45
122.41
121.99
119.28

77.55
77.23
76.91

62.67

57.55

14.03



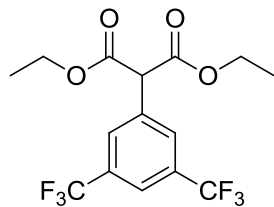


Current Data Parameters
NAME kl-2-183-F19
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150712
Time 20.21
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 131072
SOLVENT CDCl3
NS 8
DS 4
SWH 89285.711 Hz
FIDRES 0.681196 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 298.0 K
D1 1.0000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 376.4738882 MHz
NUC1 19F
P1 14.00 usec
PLW1 18.00000000 W

F2 - Processing parameters
SI 65536
SF 376.5114822 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



--62.91

--113.15



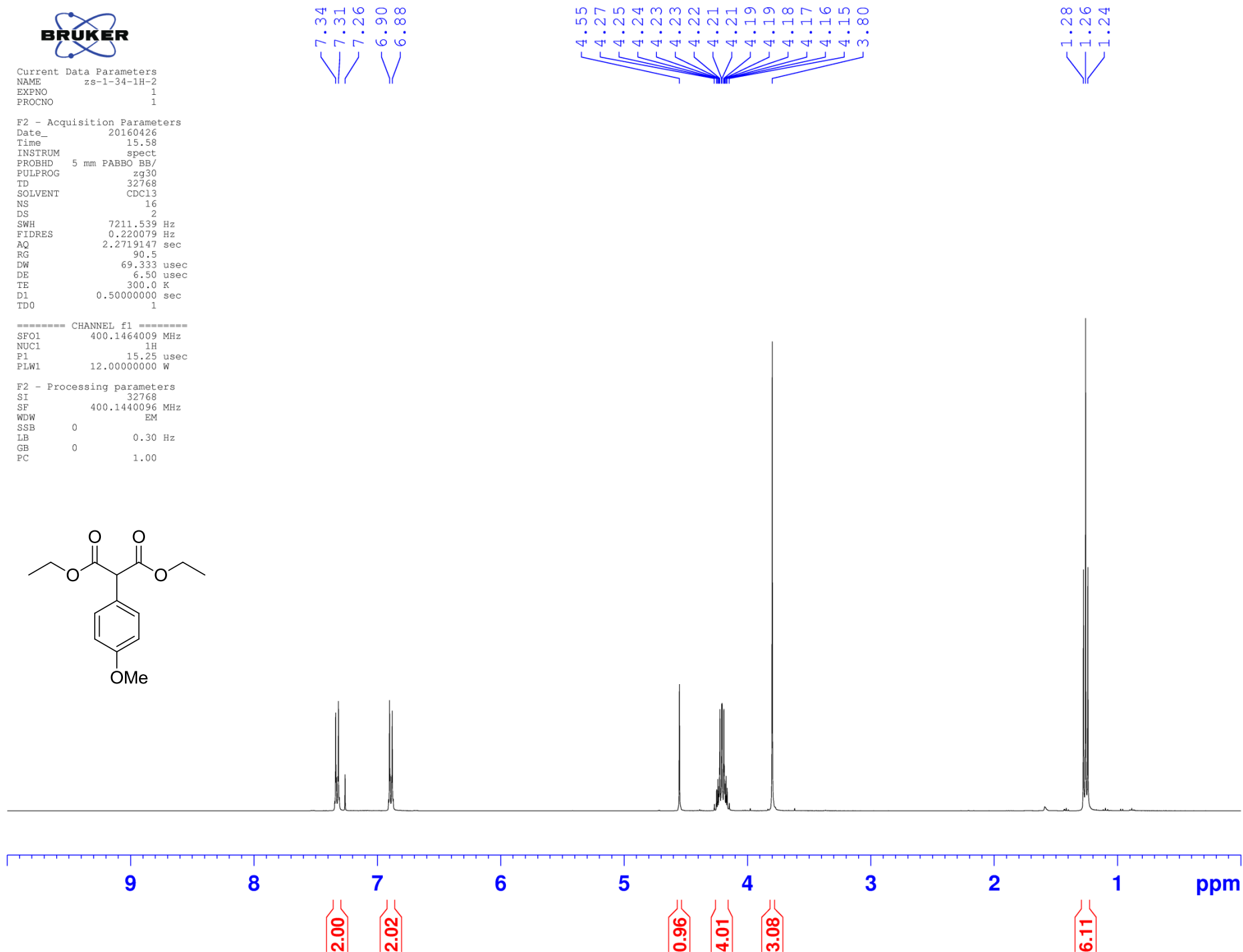
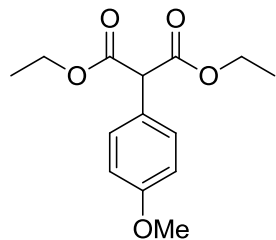


Current Data Parameters
NAME zs-1-34-1H-2
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160426
Time 15.58
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 32768
SOLVENT CDCl3
NS 16
DS 2
SWH 7211.539 Hz
FIDRES 0.220079 Hz
AQ 2.2719147 sec
RG 90.5
DW 69.333 usec
DE 6.50 usec
TE 300.0 K
D1 0.50000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 32768
SF 400.1440096 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00





Current Data Parameters
NAME zs-l-34-13C-2
EXPNO 2
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160426
Time 16.04
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 131072
SOLVENT CDCl3
NS 38
DS 4
SWH 24038.461 Hz
FIDRES 0.183399 Hz
AQ 2.7262976 sec
RG 203
DW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162693 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.40

— 168.64

— 159.69

— 130.59

— 125.16

— 114.22

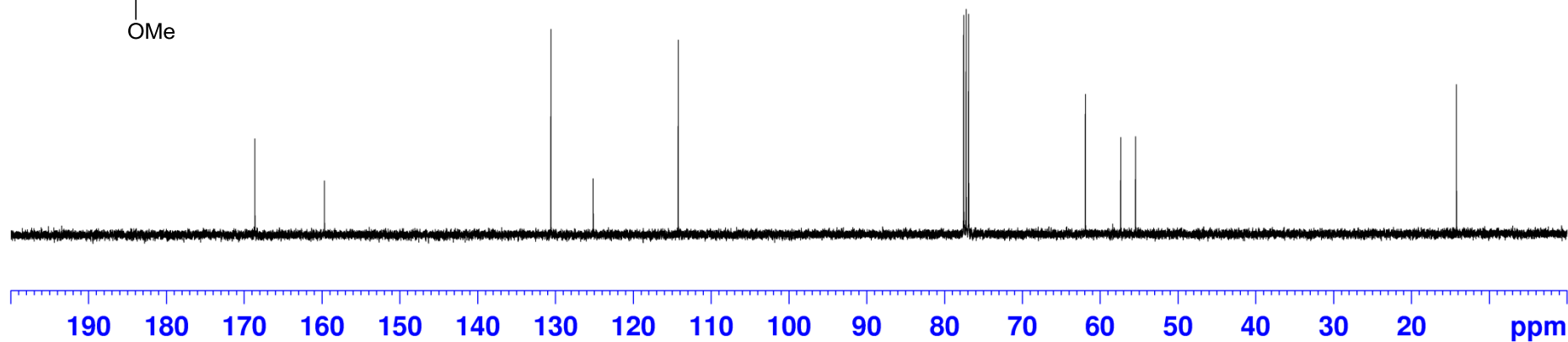
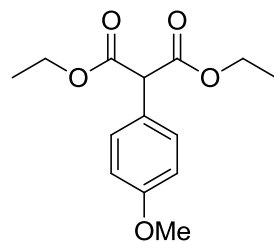
77.55
77.23
76.91

— 61.91

— 57.36

— 55.46

— 14.23



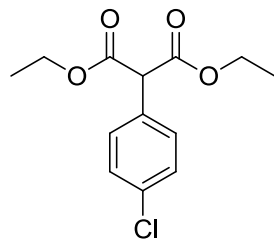


Current Data Parameters
NAME kl-2-80
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20141229
Time 15.52
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 28.5
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

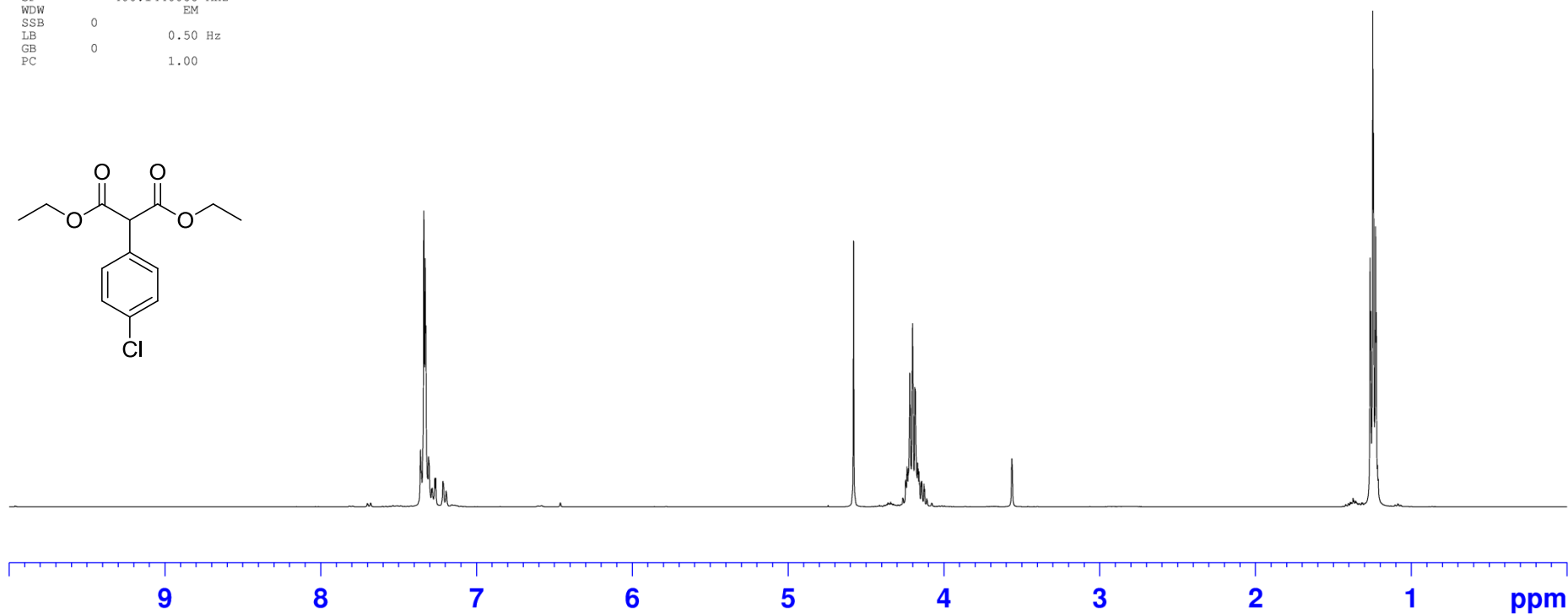
F2 - Processing parameters
SI 131072
SF 400.1440088 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00



7.36
7.35
7.34
7.33
7.32
7.31
7.31
7.30

4.58
4.25
4.24
4.24
4.23
4.23
4.22
4.22
4.20
4.20
4.19
4.18
4.17
4.17
4.16
4.16
4.16

1.26
1.25
1.23



4.04

0.98

4.00

6.43



Current Data Parameters
NAME kl-2-80-cl3a
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20141229
Time 16.01
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 8
DS 4
SWH 24038.461 Hz
FIDRES 0.550104 Hz
AQ 0.9089184 sec
RG 203
DW 20.800 usec
DE 6.50 usec
TE 300.1 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162774 MHz
WDW EM
SSB 0
LB 2.50 Hz
GB 0
PC 1.40

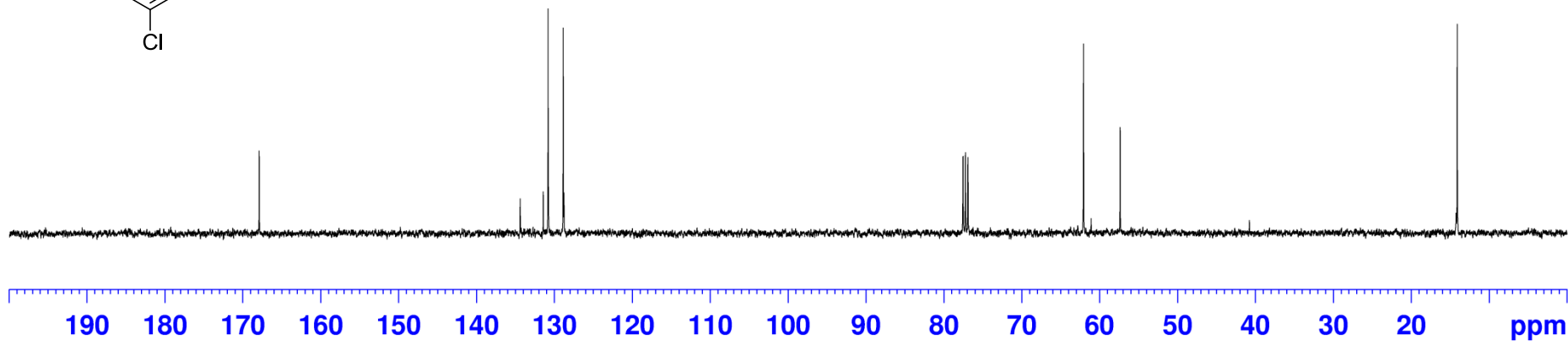
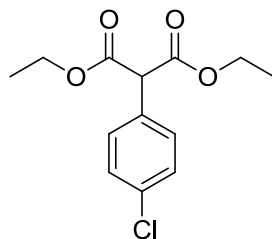
— 167.90

134.39
131.43
130.82
128.87

77.55
77.23
76.91

— 62.08
— 57.38

— 14.10





Current Data Parameters
NAME k1-2-192-H1-A
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150806
Time 14.36
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 64
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.0000000 sec
TD0 1

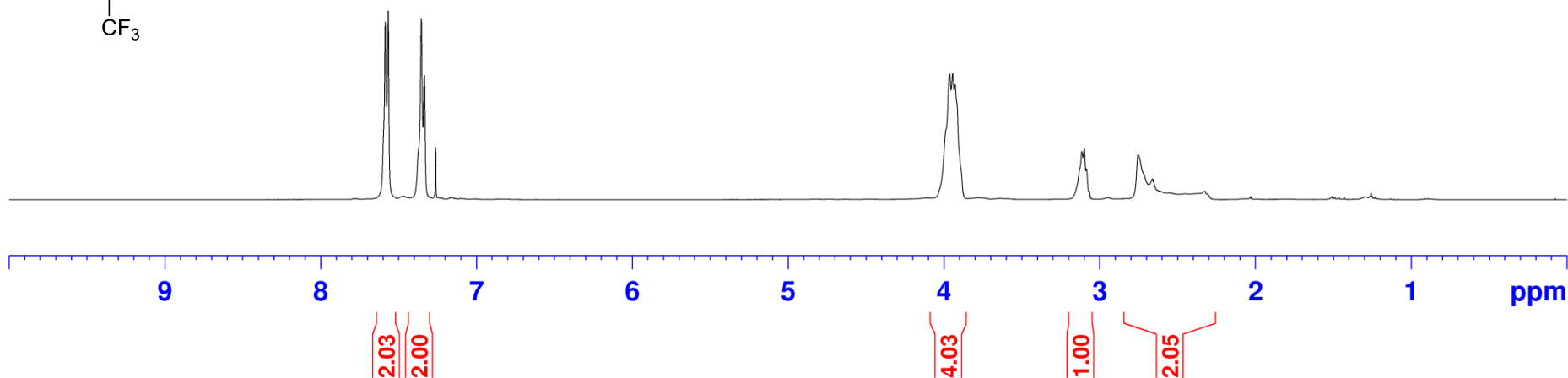
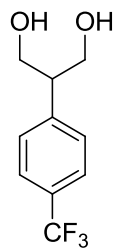
===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440095 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00

7.58
7.56
7.35
7.33
7.26

3.96
3.94
3.93

3.12
3.10
3.08
2.75
2.66
2.32





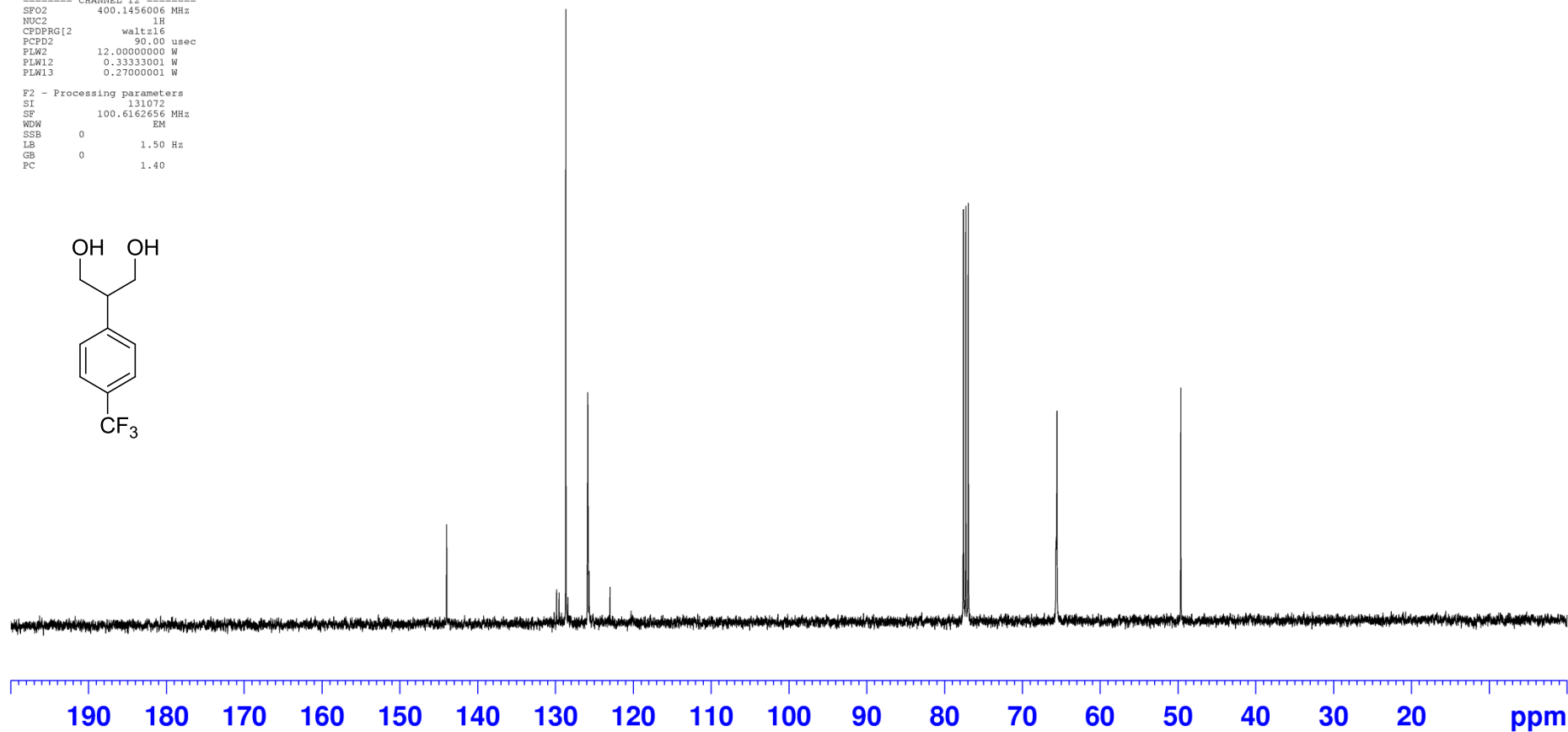
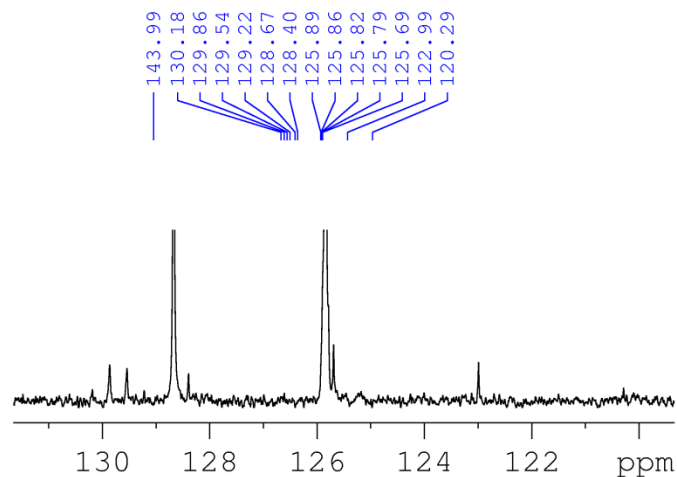
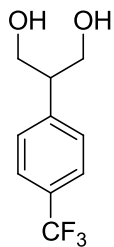
Current Data Parameters
NAME kl-2-192-cl3
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150806
Time 14.46
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 151
DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
AQ 0.8652204 sec
RG 203
DW 19.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162656 MHz
WDW EM
SSB 0
LB 1.50 Hz
GB 0
PC 1.40



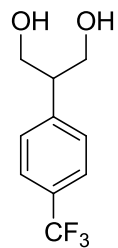


Current Data Parameters
NAME k1-2-192-f19
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150806
Time 14.50
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 131072
SOLVENT CDCl3
NS 8
DS 4
SWH 89285.711 Hz
FIDRES 0.681196 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 1.00000000 sec
TD0 1

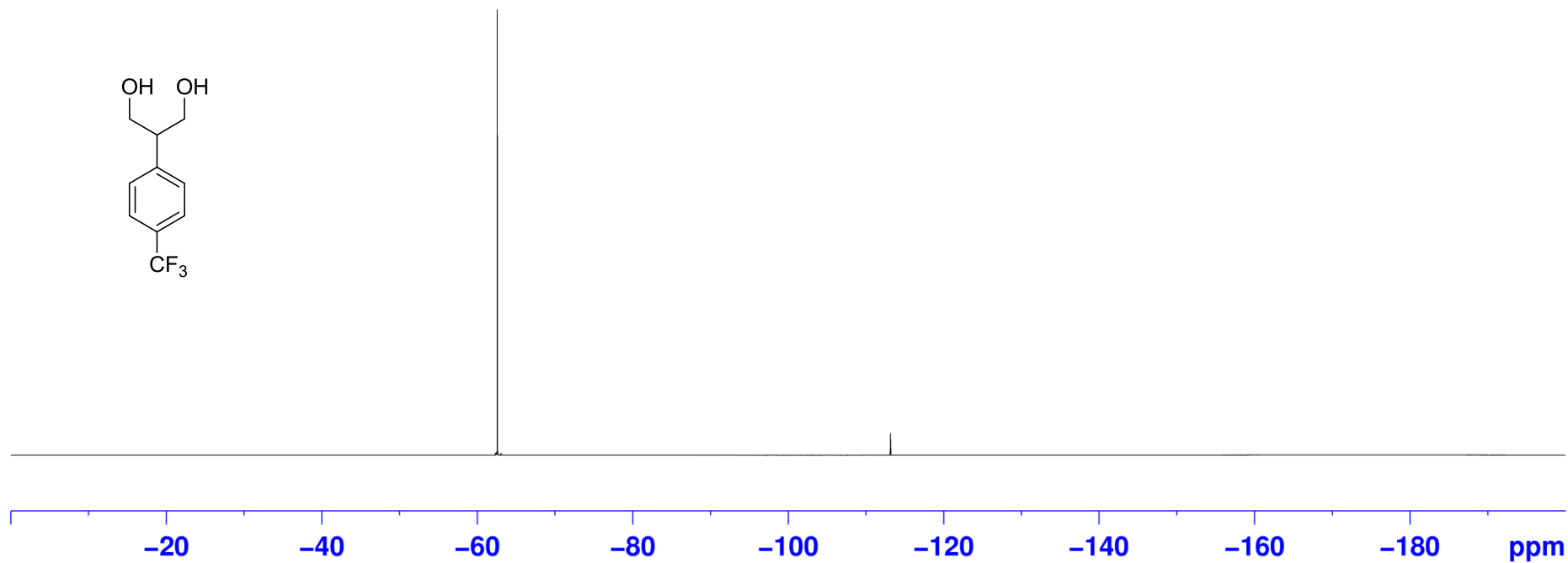
===== CHANNEL f1 =====
SFO1 376.4738882 MHz
NUC1 19F
P1 14.00 usec
PLW1 18.00000000 W

F2 - Processing parameters
SI 65536
SF 376.5115466 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



— -62.57

— -113.15





Current Data Parameters
NAME k1-2-193-1H
EXPNO 1
PROCNO 1

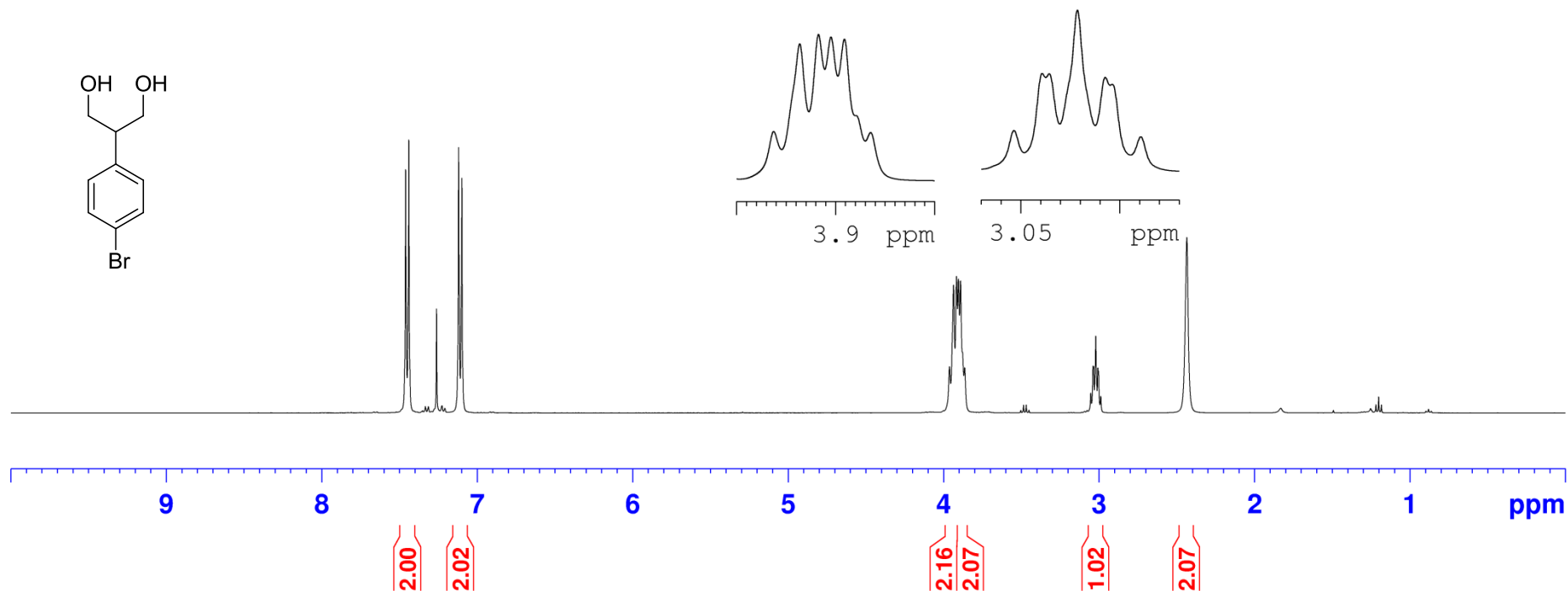
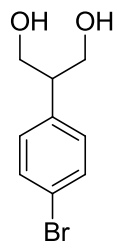
F2 - Acquisition Parameters
Date_ 20150823
Time 22.54
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 71.8
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440097 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00

7.46
7.44
7.26
7.12
7.10

3.96
3.94
3.92
3.90
3.89
3.86
3.05
3.04
3.04
3.02
3.01
3.00
2.99
2.44





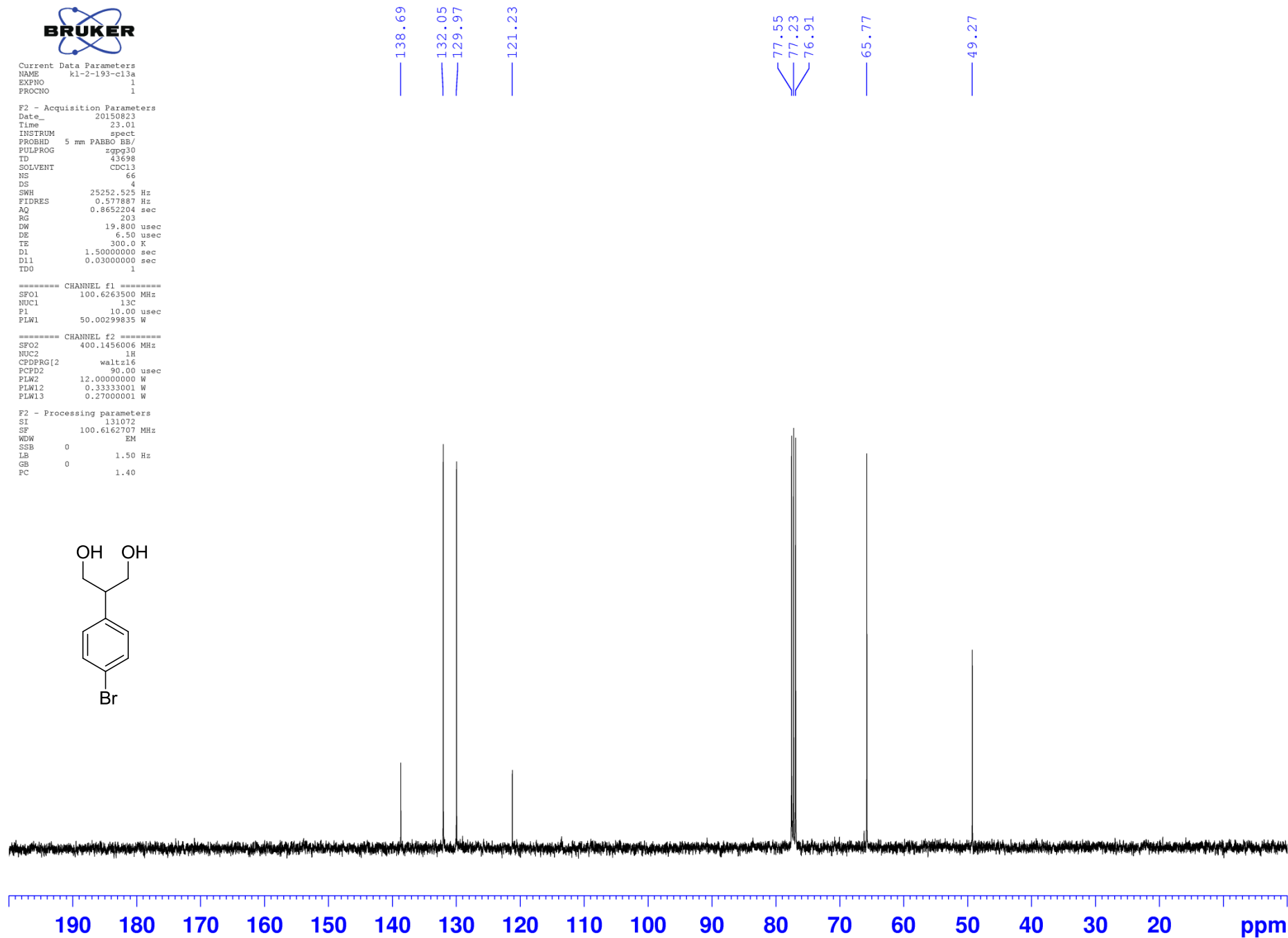
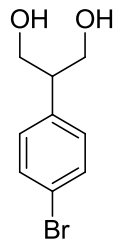
Current Data Parameters
NAME kl-2-193-cl3a
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150823
Time 23.01
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 66
DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
AQ 0.8652204 sec
RG 203
DW 19.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162707 MHz
WDW EM
SSB 0
LB 1.50 Hz
GB 0
PC 1.40





Current Data Parameters
NAME kl-2-85-H1
EXPNO 1
PROCNO 1

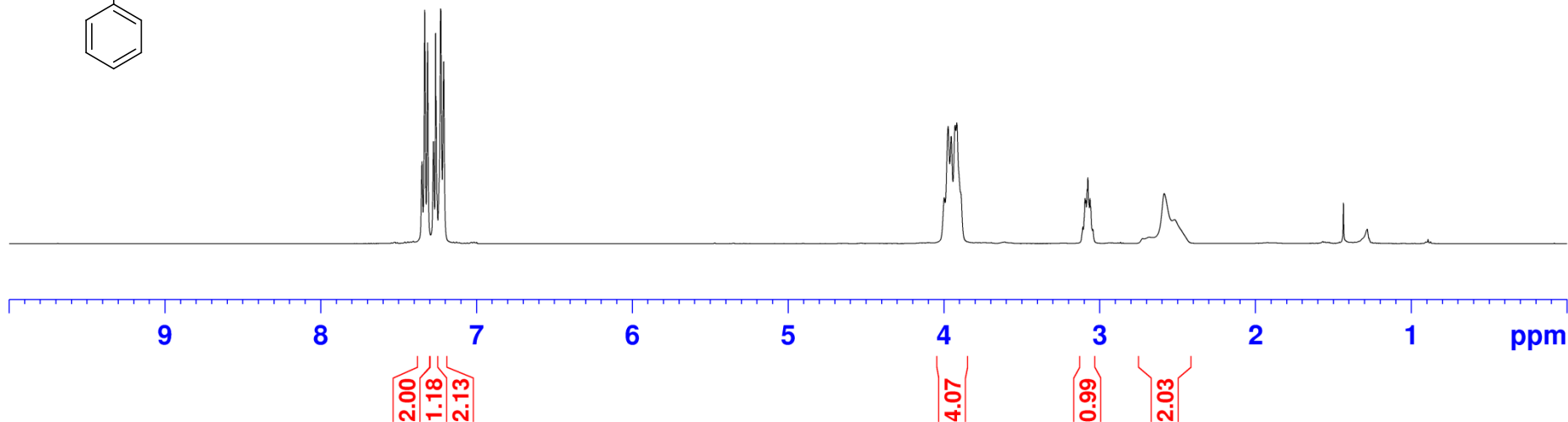
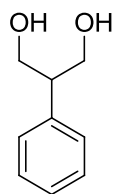
F2 - Acquisition Parameters
Date_ 20141126
Time 16.32
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 64
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440080 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00

7.35
7.33
7.31
7.28
7.26
7.26
7.23
7.23
7.21

4.00
3.97
3.95
3.93
3.92
3.11
3.09
3.09
3.08
3.08
3.06
3.04
2.59





Current Data Parameters
NAME kl-2-85-Cl3
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20141126
Time 16.36
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 26
DS 4
SWH 24038.461 Hz
FIDRES 0.550104 Hz
AQ 0.9089184 sec
RG 203
DW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162717 MHz
WDW EM
SSB 0
LB 2.50 Hz
GB 0
PC 1.40

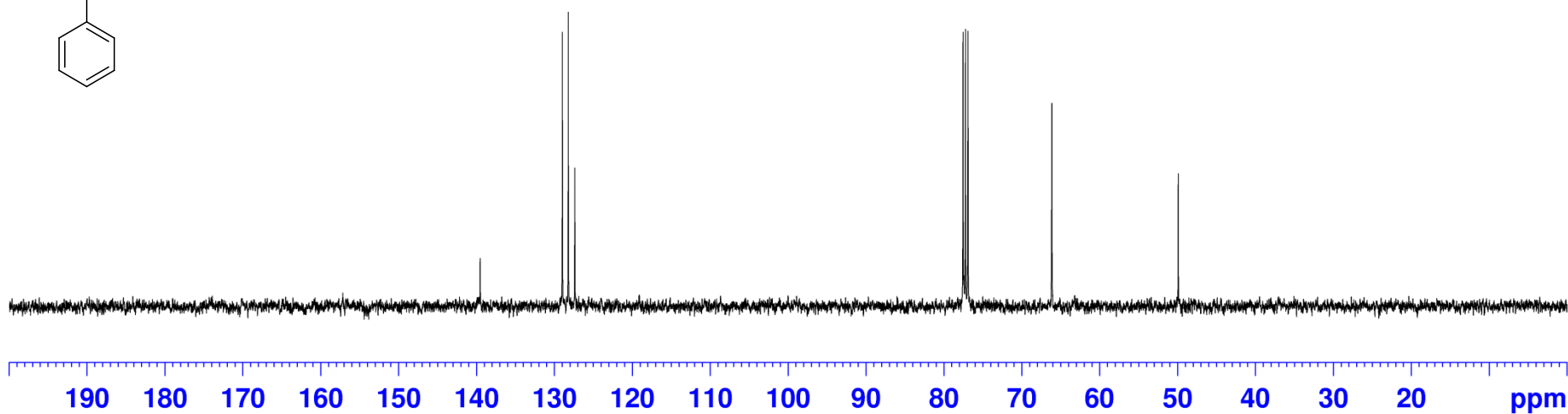
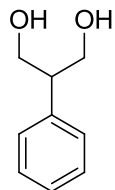
— 139.53

128.98
128.22
127.39

77.55
77.23
76.91

— 66.15

— 49.91



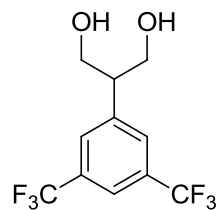


Current Data Parameters
NAME kl-2-186-H1
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150715
Time 15.20
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 80.6
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

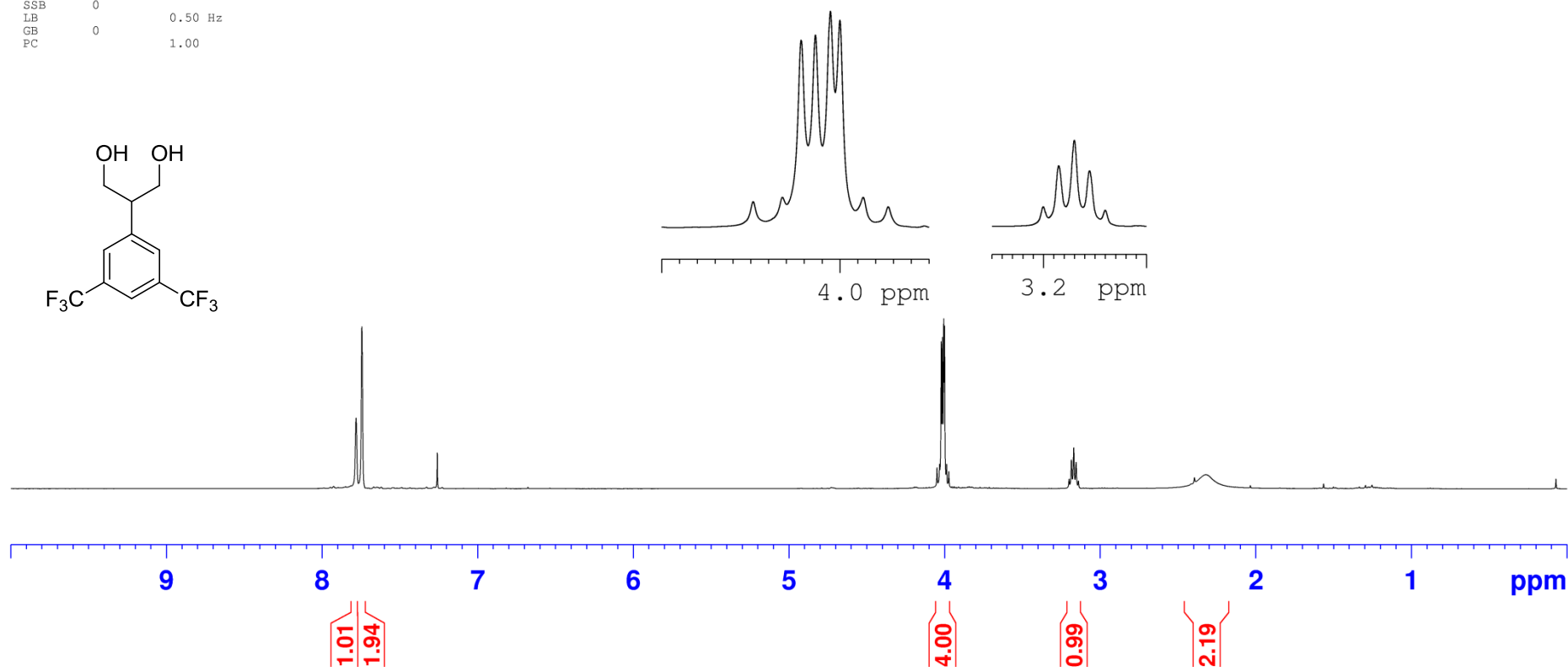
===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440099 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00



7.78
7.74
7.26

4.05
4.03
4.02
4.01
4.01
4.00
3.99
3.97
3.20
3.19
3.17
3.16
3.14
2.32





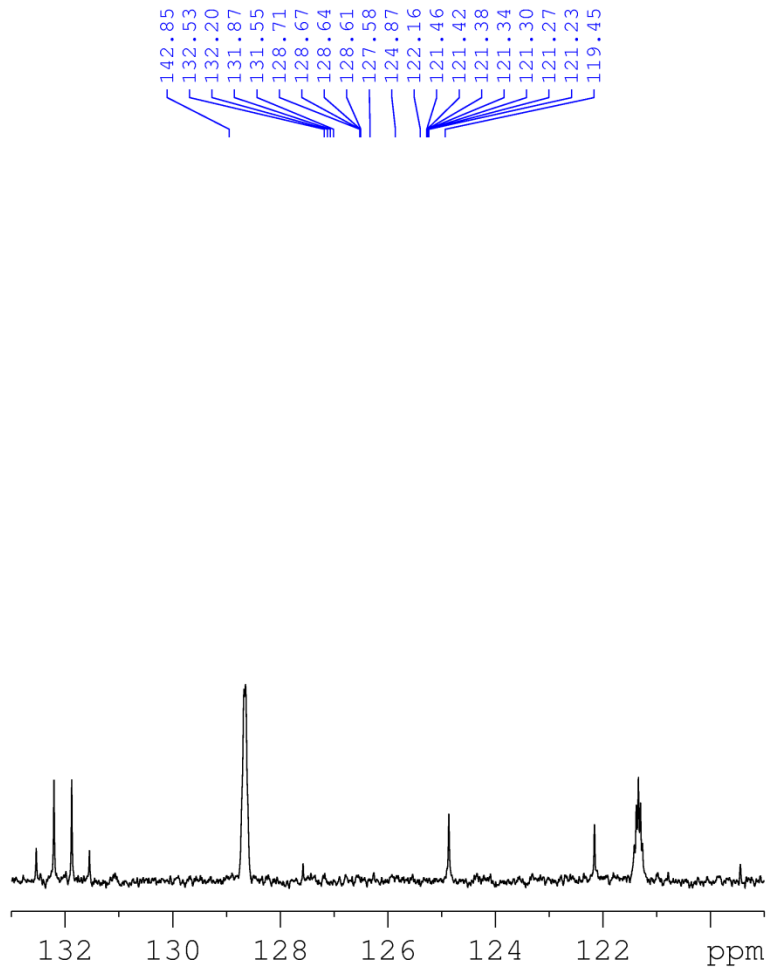
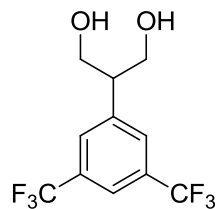
Current Data Parameters
NAME kl-2-186-Cl3
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150715
Time 15.40
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 400
DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
AQ 0.8652204 sec
RG 203
DW 19.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.270000001 W

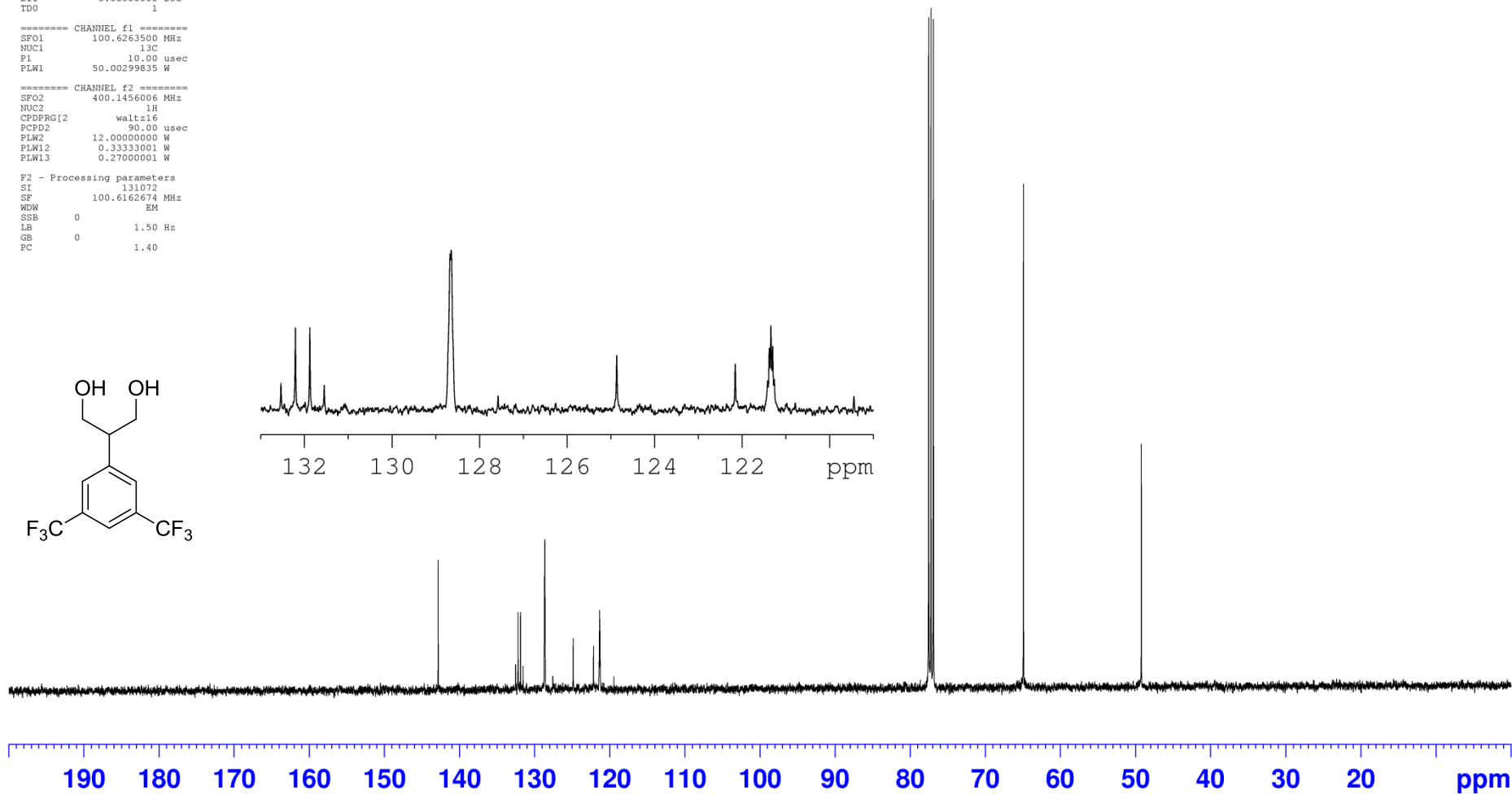
F2 - Processing parameters
SI 131072
SF 100.6162674 MHz
WDW EM
SSB 0
LB 1.50 Hz
GB 0
PC 1.40



77.55
77.23
76.91

64.93

49.23



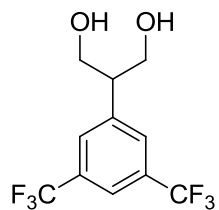


Current Data Parameters
NAME kl-2-186-F19
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150716
Time 13.38
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 131072
SOLVENT CDCl3
NS 8
DS 4
SWH 89285.711 Hz
FIDRES 0.681196 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 1.00000000 sec
TD0 1

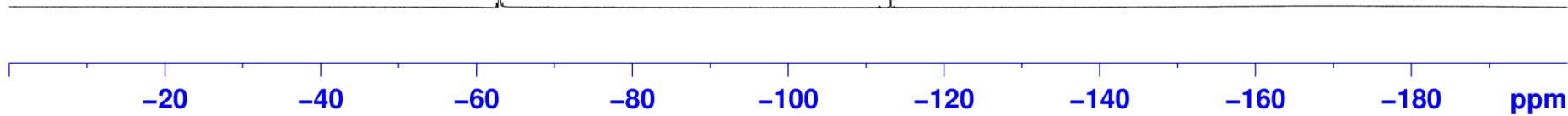
===== CHANNEL f1 =====
SFO1 376.4738882 MHz
NUC1 19F
P1 14.00 usec
PLW1 18.00000000 W

F2 - Processing parameters
SI 65536
SF 376.5115656 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



— -62.87

-113.11
-113.13
-113.14
-113.15
-113.17
-113.18
-113.19



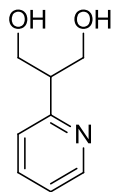


Current Data Parameters
NAME pyridyldiol
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150609
Time 12.35
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 40.3
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

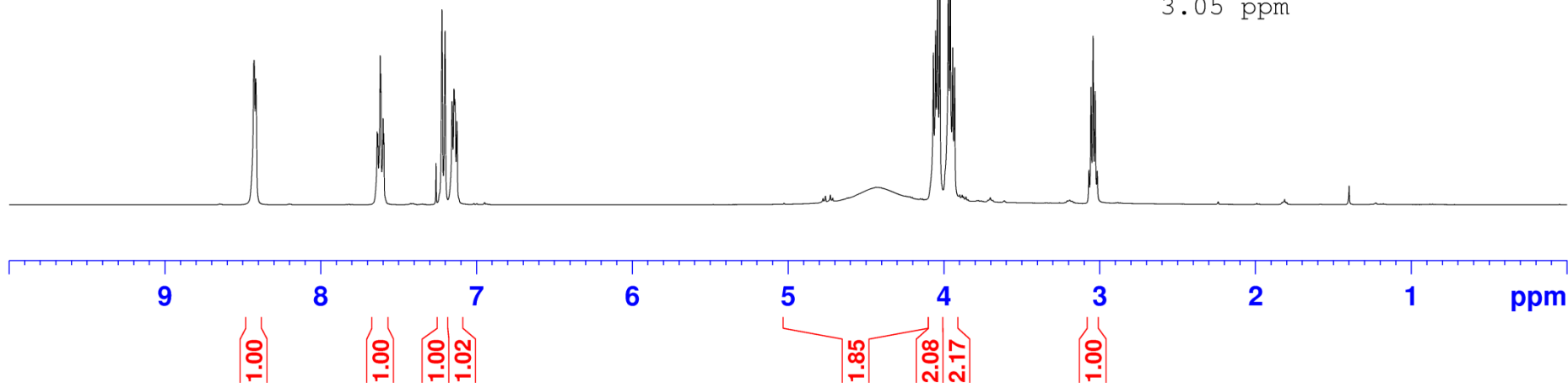
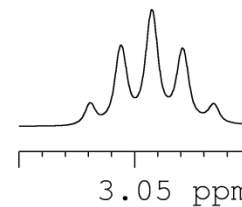
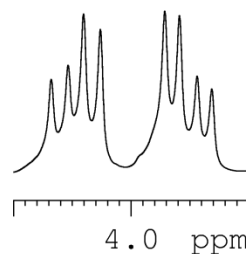
===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440096 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00



8.43
8.42
7.64
7.63
7.62
7.61
7.60
7.59
7.26
7.22
7.20
7.16
7.14
7.13

4.44
4.07
4.05
4.04
4.03
3.97
3.96
3.94
3.93
3.07
3.06
3.04
3.03
3.02





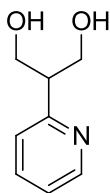
Current Data Parameters
NAME pyridyldiol-cl3
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150609
Time 12.42
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 43
DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
AQ 0.8652204 sec
RG 203
DW 19.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162756 MHz
WDW EM
SSB 0
LB 1.50 Hz
GB 0
PC 1.40



— 161.65

— 148.72

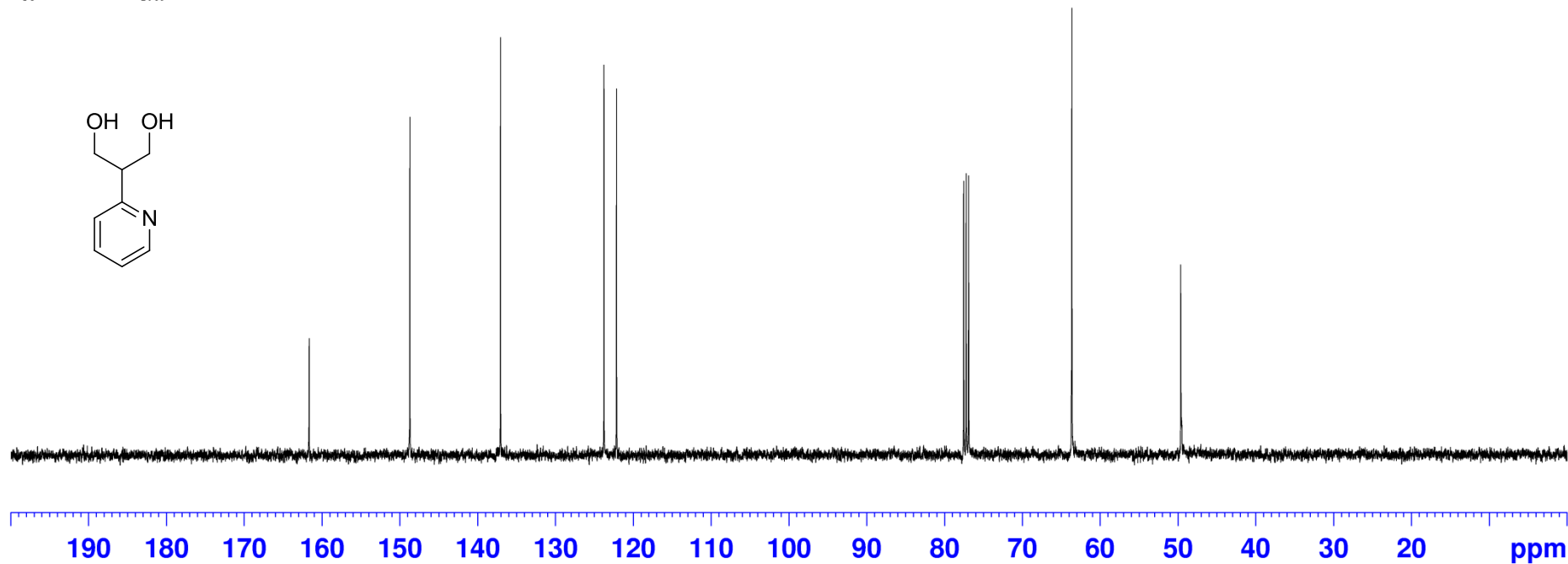
— 137.07

— 123.77
— 122.16

77.55
77.23
76.91

— 63.63

— 49.65





Current Data Parameters
NAME zs-1-35-1H-2
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160509
Time 14.12
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 32768
SOLVENT CDCl3
NS 16
DS 2
SWH 7211.539 Hz
FIDRES 0.220079 Hz
AQ 2.2719147 sec
RG 203
DW 69.333 usec
DE 6.50 usec
TE 299.9 K
D1 0.50000000 sec
TD0 1

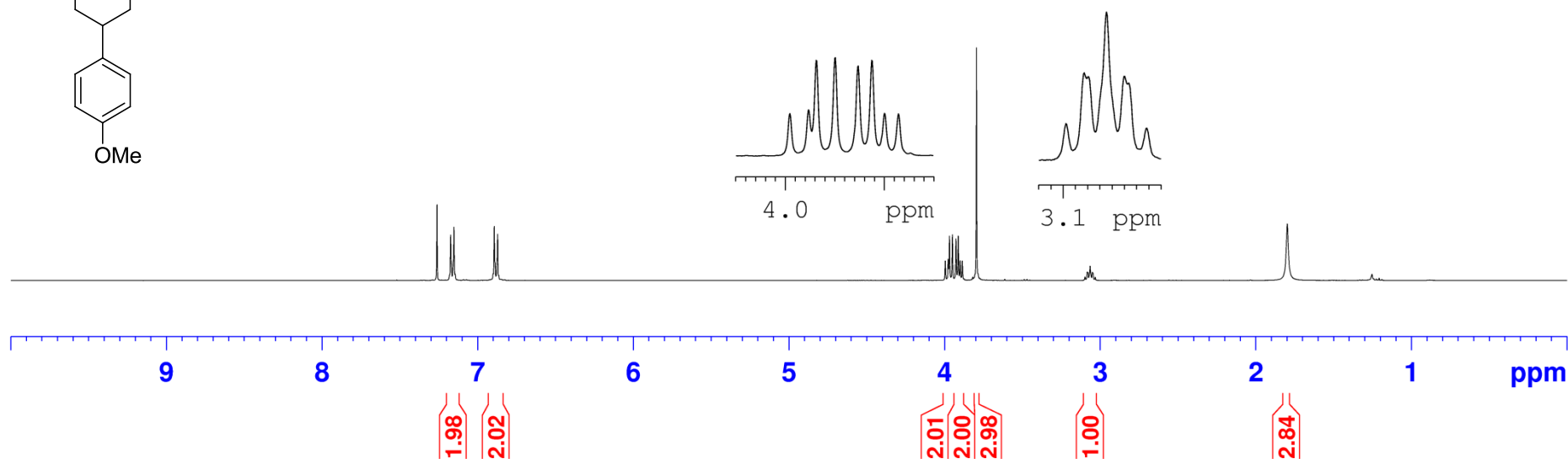
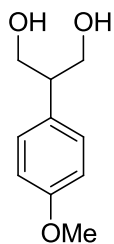
===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 32768
SF 400.1440098 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

7.26
7.17
7.15
6.89
6.87

4.00
3.98
3.97
3.95
3.93
3.91
3.90
3.89
3.79
3.10
3.08
3.08
3.06
3.05
3.03

1.80





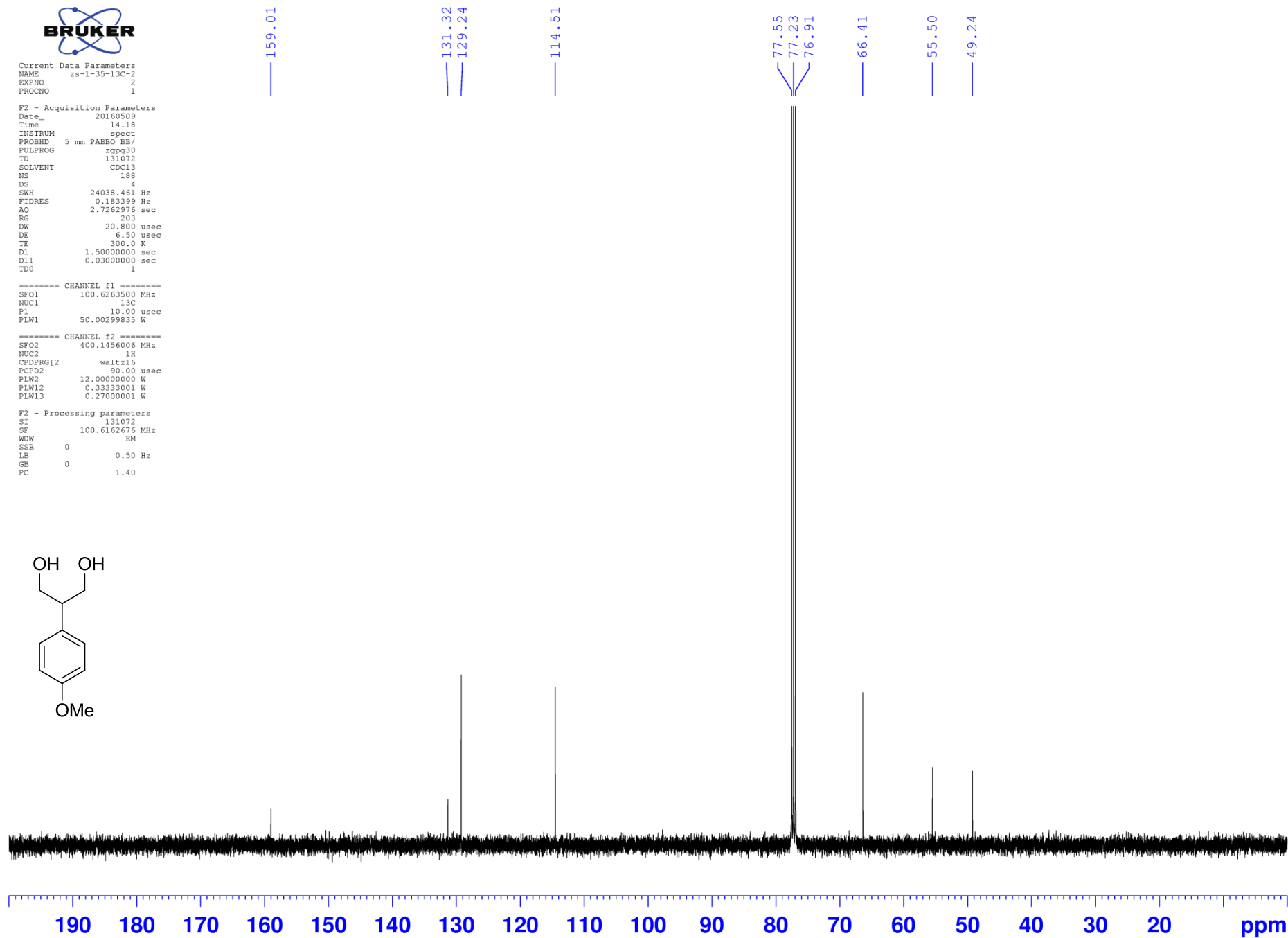
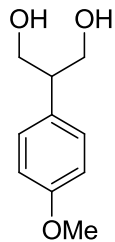
Current Data Parameters
NAME zs-l-35-13C-2
EXPNO 2
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160509
Time 14.18
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 131072
SOLVENT CDCl3
NS 188
DS 4
SWH 24038.461 Hz
FIDRES 0.183399 Hz
AQ 2.7262976 sec
RG 203
DW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162676 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.40



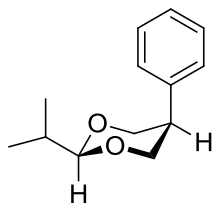


Current Data Parameters
NAME kl-2-88-Minor
EXPNO 1
PROCNO 1

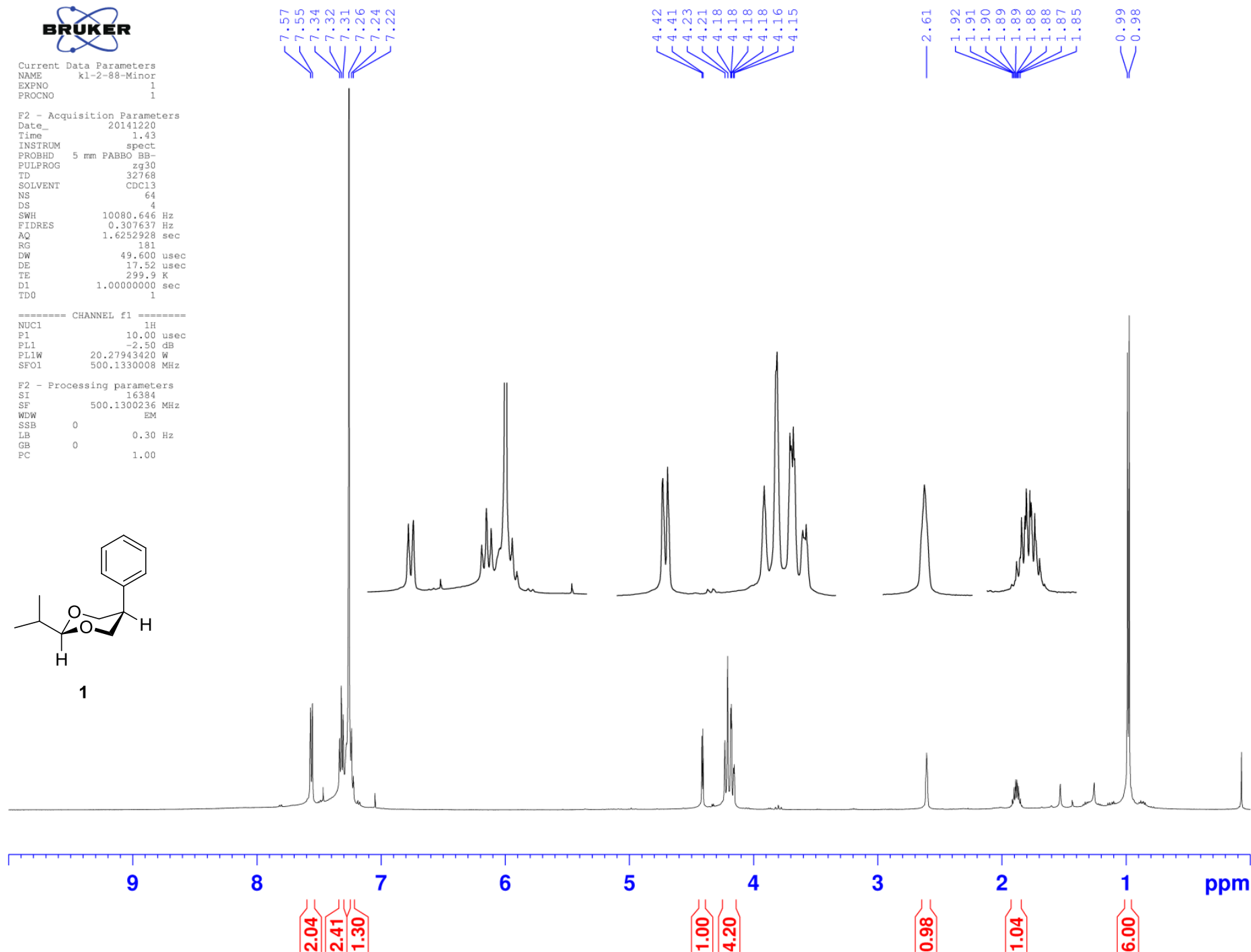
F2 - Acquisition Parameters
Date_ 20141220
Time 1.43
INSTRUM spect
PROBHD 5 mm PABBO BB-
PULPROG zg30
TD 32768
SOLVENT CDCl3
NS 64
DS 4
SWH 10080.646 Hz
FIDRES 0.307637 Hz
AQ 1.6252928 sec
RG 181
DW 49.600 usec
DE 17.52 usec
TE 299.9 K
D1 1.00000000 sec
TD0 1

===== CHANNEL f1 =====
NUC1 1H
P1 10.00 usec
PL1 -2.50 dB
PL1W 20.27943420 W
SFO1 500.1330008 MHz

F2 - Processing parameters
SI 16384
SF 500.1300236 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



1

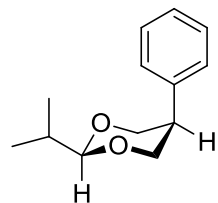




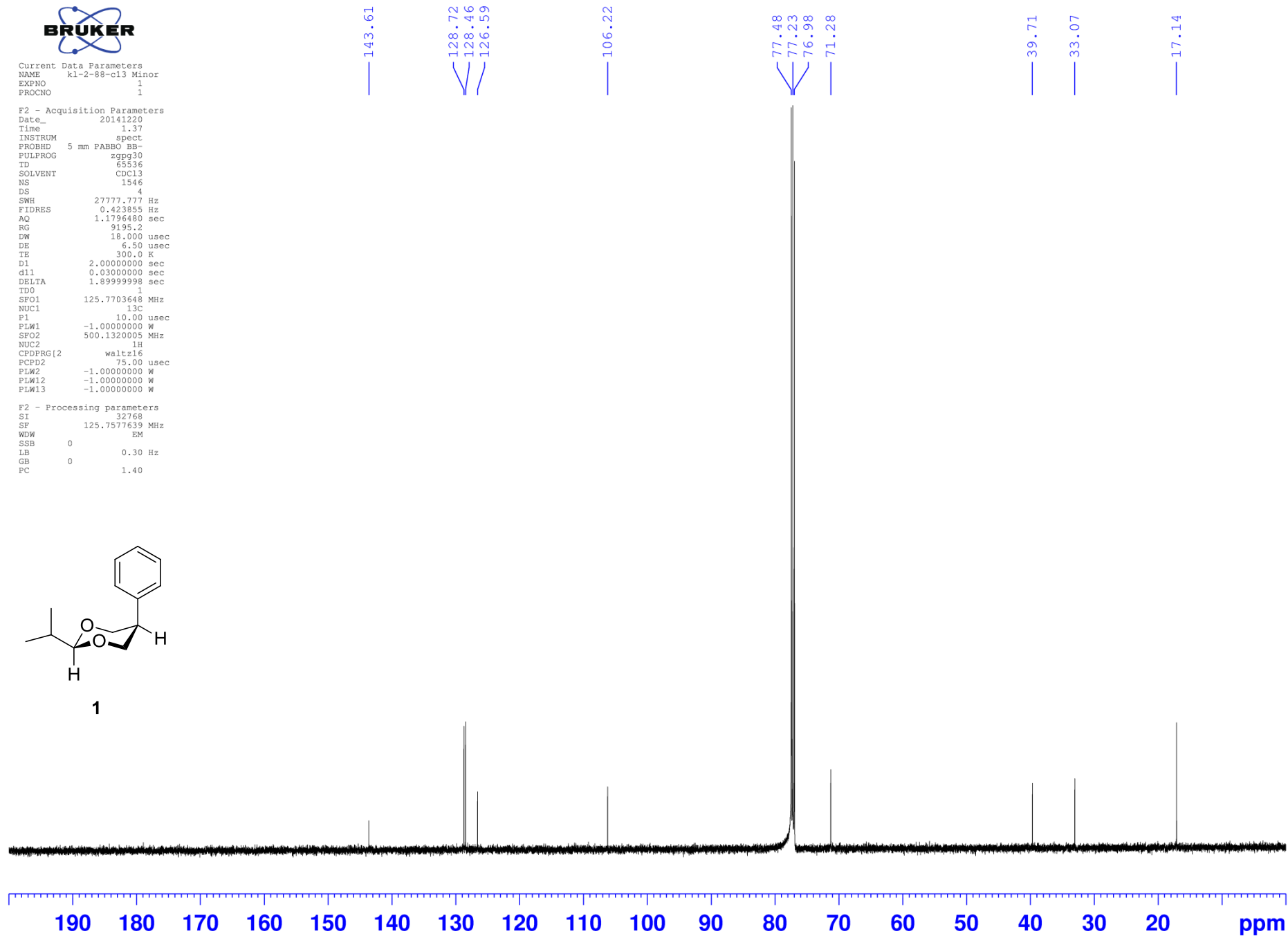
Current Data Parameters
NAME kl-2-88-cl3 Minor
EXPNO 1
PROCNO 1

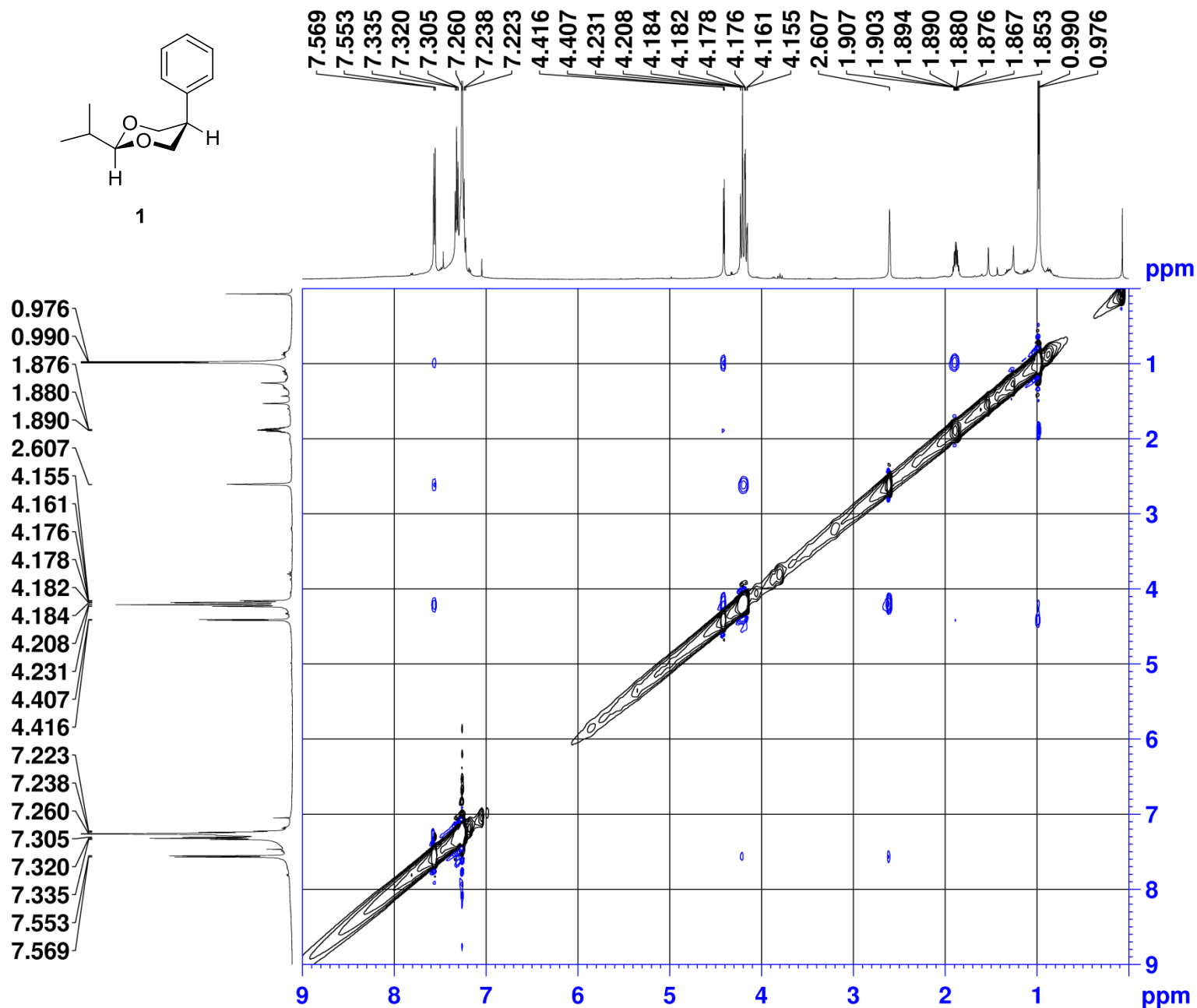
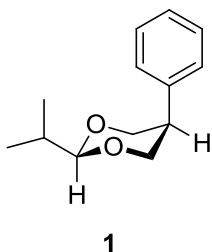
F2 - Acquisition Parameters
Date_ 20141220
Time 1.37
INSTRUM spect
PROBHD 5 mm PABBO BB-
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 1546
DS 4
SWH 27777.777 Hz
FIDRES 0.423855 Hz
AQ 1.1796480 sec
RG 9195.2
DW 18.000 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
d11 0.03000000 sec
DELTA 1.89999998 sec
TDO 1
SFO1 125.7703648 MHz
NUC1 13C
P1 10.00 usec
PLW1 -1.00000000 W
SFO2 500.1320005 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 75.00 usec
PLW2 -1.00000000 W
PLW12 -1.00000000 W
PLW13 -1.00000000 W

F2 - Processing parameters
SI 32768
SF 125.7577639 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.40



1





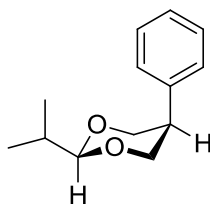
Current Data Parameters
 NAME Kl-2-88-Minor-1HNOESY
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20141220
 Time 2.27
 INSTRUM spect
 PROBHD 5 mm PABBO BB-
 PULPROG noesygpph
 TD 4096
 SOLVENT CDCl3
 NS 8
 DS 16
 SWH 10080.646 Hz
 FIDRES 2.461095 Hz
 AQ 0.2031616 sec
 RG 128
 DW 49.600 usec
 DE 6.50 usec
 TE 300.0 K
 d0 -0.00001273 sec
 D1 2.00000000 sec
 D8 0.80000001 sec
 d11 0.03000000 sec
 d12 0.00002000 sec
 D16 0.00010000 sec
 in0 0 sec
 STICNT 0
 TAU 0.39890000 sec
 d0orig -0.00001273 sec
 phloop 0
 t1loop 0
 SFO1 500.1332008 MHz
 NUC1 1H
 P1 10.00 usec
 p2 20.00 usec
 P17 2500.00 usec
 PLW1 -1.00000000 W
 PLW10 -1.00000000 W
 GENAM[1] SINE.100
 GPZ1 80.00 %
 P16 1000.00 usec

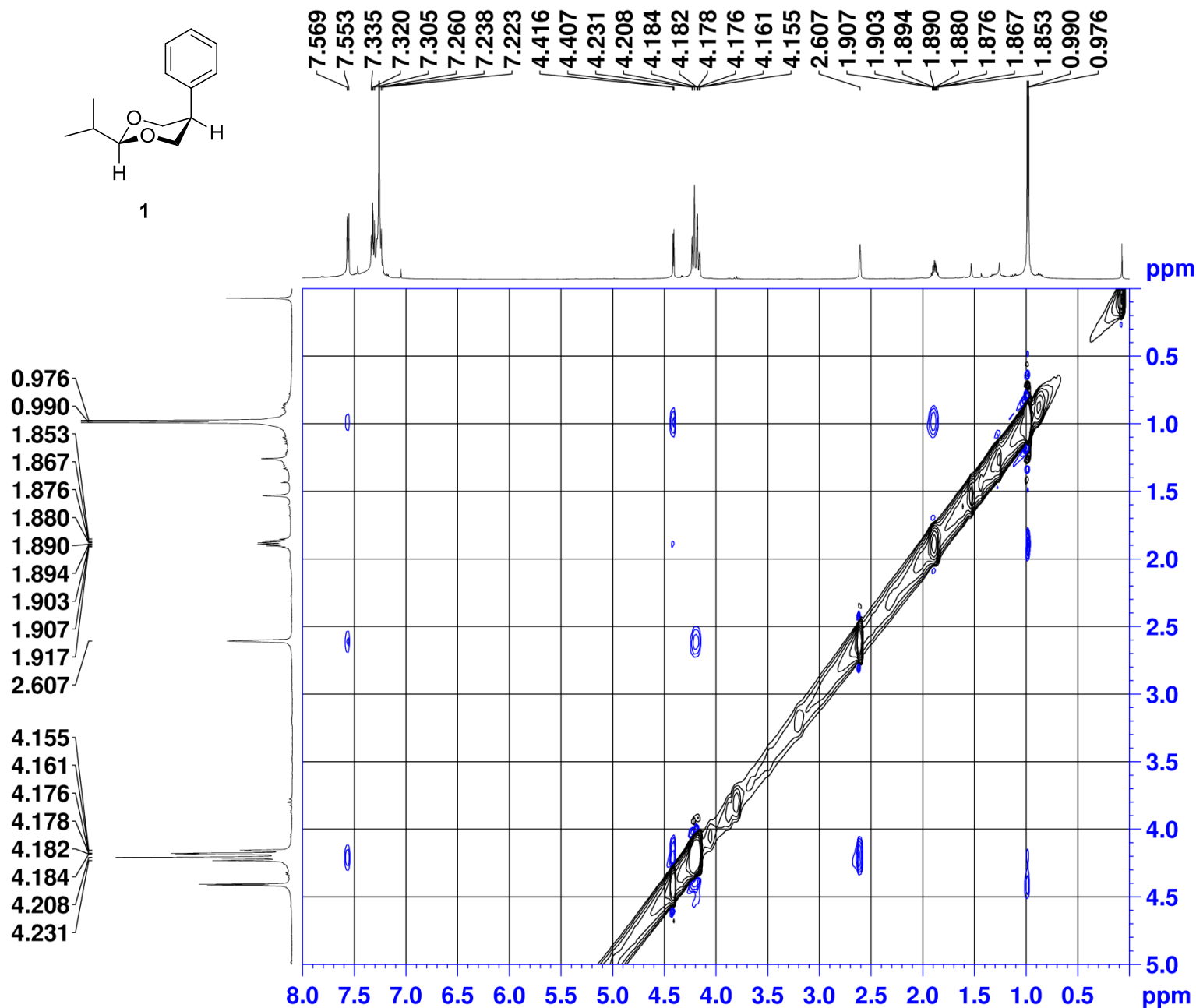
F1 - Acquisition parameters
 TD 256
 SFO1 500.1332 MHz
 FIDRES 39.377480 Hz
 SW 20.156 ppm
 FnMODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 500.1300178 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 500.1300178 MHz
 WDW TRAP
 SSB 2
 LB 0 Hz
 GB 0



1



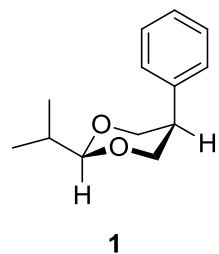
Current Data Parameters
NAME Kl-2-88-Minor-1HNOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20141220
Time 2.27
INSTRUM spect
PROBHD 5 mm PABBO BB-
PULPROG noesygpph
TD 4096
SOLVENT CDCl3
NS 8
DS 16
SWH 10080.646 Hz
FIDRES 2.461095 Hz
AQ 0.2031616 sec
RG 128
DW 49.600 usec
DE 6.50 usec
TE 300.0 K
d0 -0.00001273 sec
D1 2.00000000 sec
D8 0.80000001 sec
d11 0.03000000 sec
d12 0.00002000 sec
D16 0.00010000 sec
in0 0 sec
STICNT 0
TAU 0.39890000 sec
d0orig -0.00001273 sec
phloop 0
t1loop 0
SFO1 500.1332008 MHz
NUC1 1H
P1 10.00 usec
p2 20.00 usec
P17 2500.00 usec
PLW1 -1.00000000 W
PLW10 -1.00000000 W
GENAM[1] SINE.100
GPZ1 80.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 500.1332 MHz
FIDRES 39.377480 Hz
SW 20.156 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 500.1300178 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 500.1300178 MHz
WDW TRAP
SSB 2
LB 0 Hz
GB 0

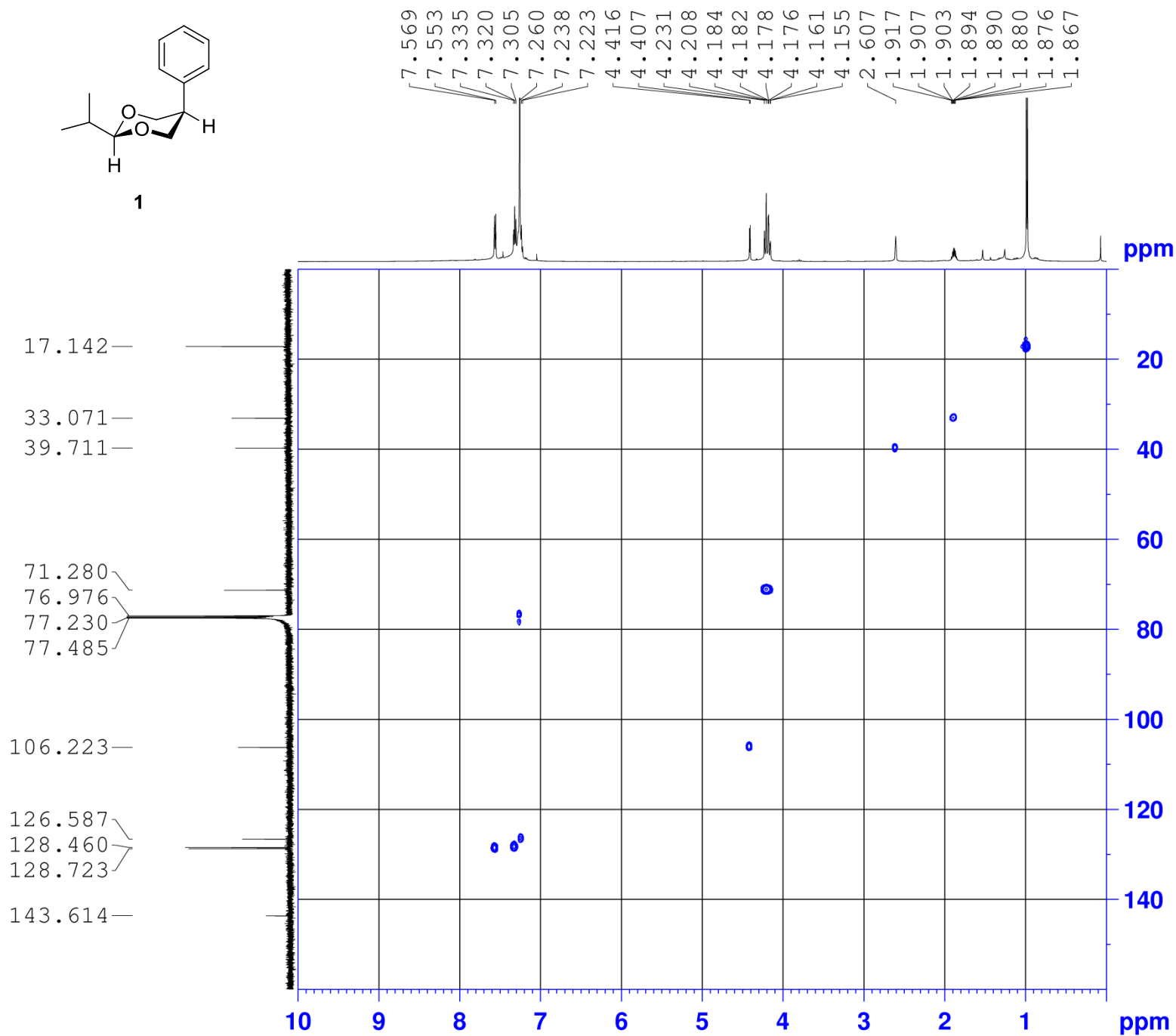


Current Data Parameters
 NAME k1-2-88-Minor
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20141220
 Time 1.43
 INSTRUM spect
 PROBHD 5 mm PABBO BB-
 PULPROG zg30
 TD 32768
 SOLVENT CDCl3
 NS 64
 DS 4
 SWH 10080.646 Hz
 FIDRES 0.307637 Hz
 AQ 1.6252928 sec
 RG 181
 DW 49.600 usec
 DE 17.52 usec
 TE 299.9 K
 D1 1.00000000 sec
 TD0 1

===== CHANNEL f1 =====
 NUC1 1H
 P1 10.00 usec
 PL1 -2.50 dB
 PL1W 20.27943420 W
 SFO1 500.1330008 MHz

F2 - Processing parameters
 SI 16384
 SF 500.1300236 MHz
 WDW EM
 SSB 0
 LB 0.30 Hz
 GB 0
 PC 1.00



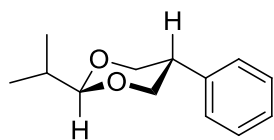


Current Data Parameters
NAME k1-2-88-eq Phenyl%3F
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20141212
Time 19.31
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 50.8
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440096 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00



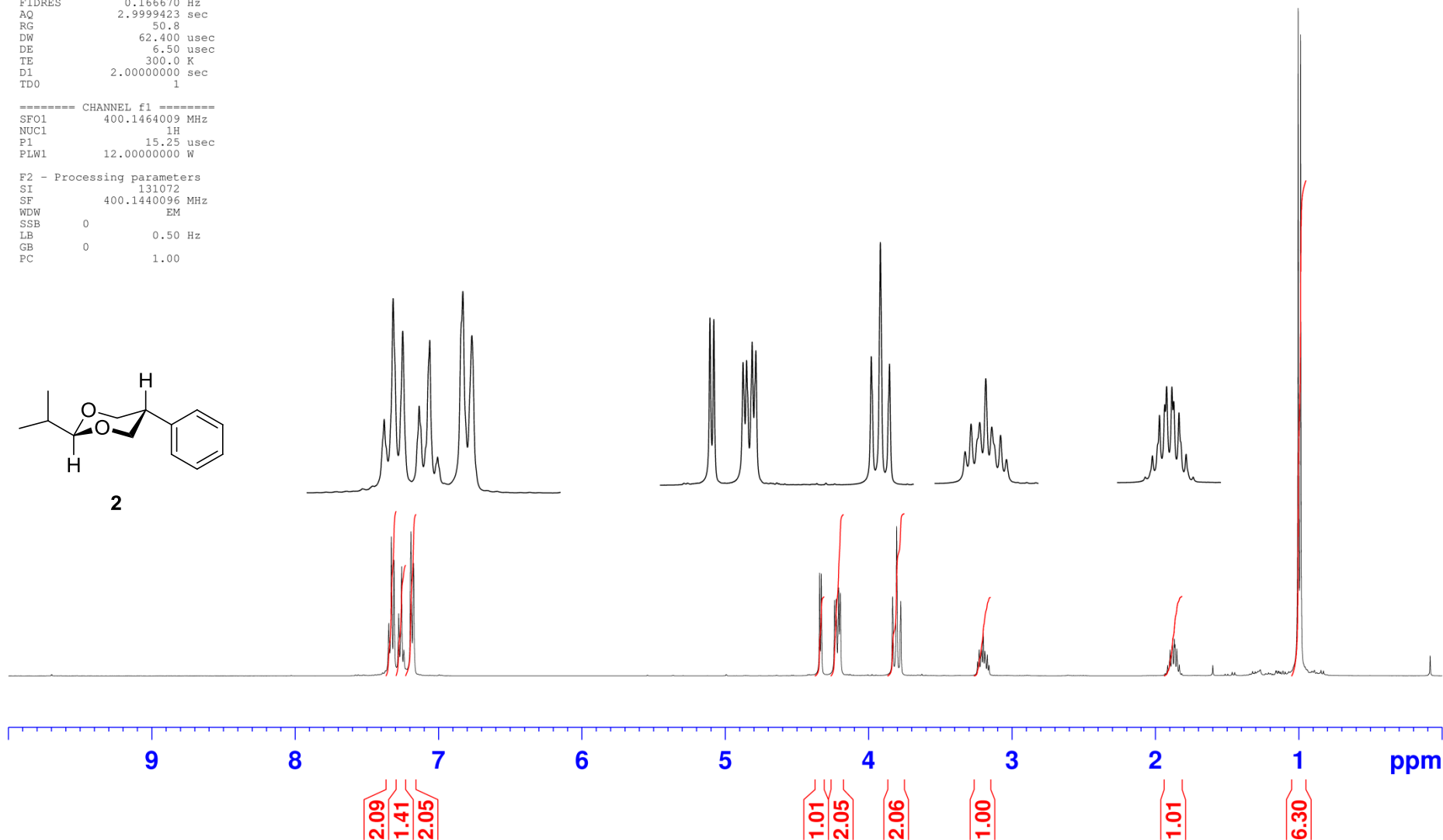
2

7.35
7.33
7.31
7.28
7.26
7.24
7.19
7.17

4.34
4.33
4.24
4.23
4.21
4.20
3.83
3.81
3.78
3.24
3.23
3.21
3.20
3.19
3.17
3.16

1.91
1.90
1.89
1.88
1.87
1.86
1.85
1.83

1.00
0.99





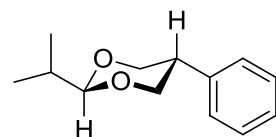
Current Data Parameters
NAME kl-2-88-eq Phenyl%3F - C13
EXFNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20141212
Time 19.39
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 89
DS 4
SWH 24038.461 Hz
FIDRES 0.550104 Hz
AQ 0.9089184 sec
RG 203
DW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

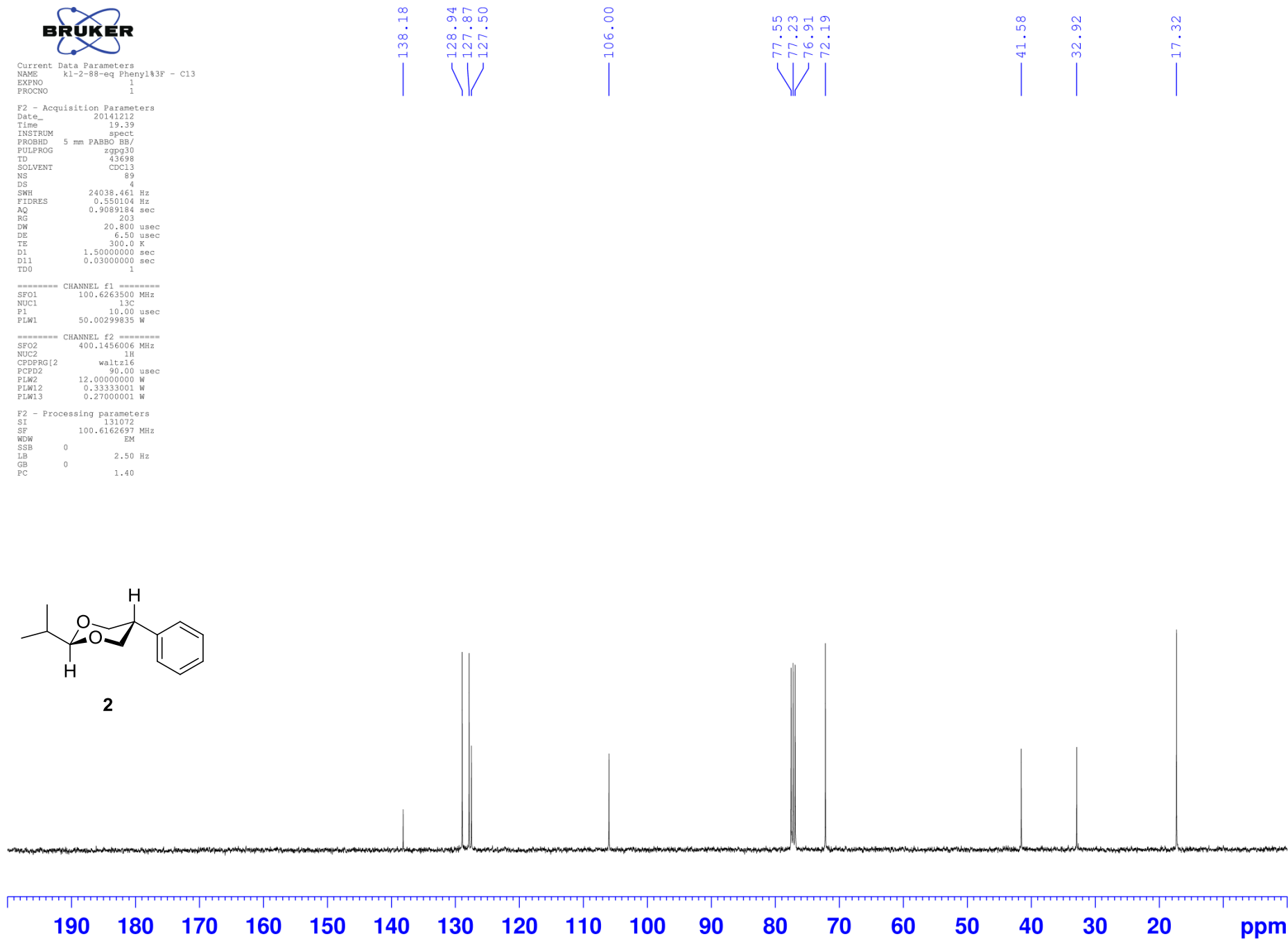
===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

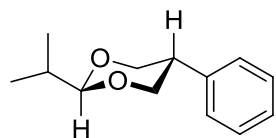
===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162697 MHz
WDW EM
SSB 0
LB 2.50 Hz
GB 0
PC 1.40

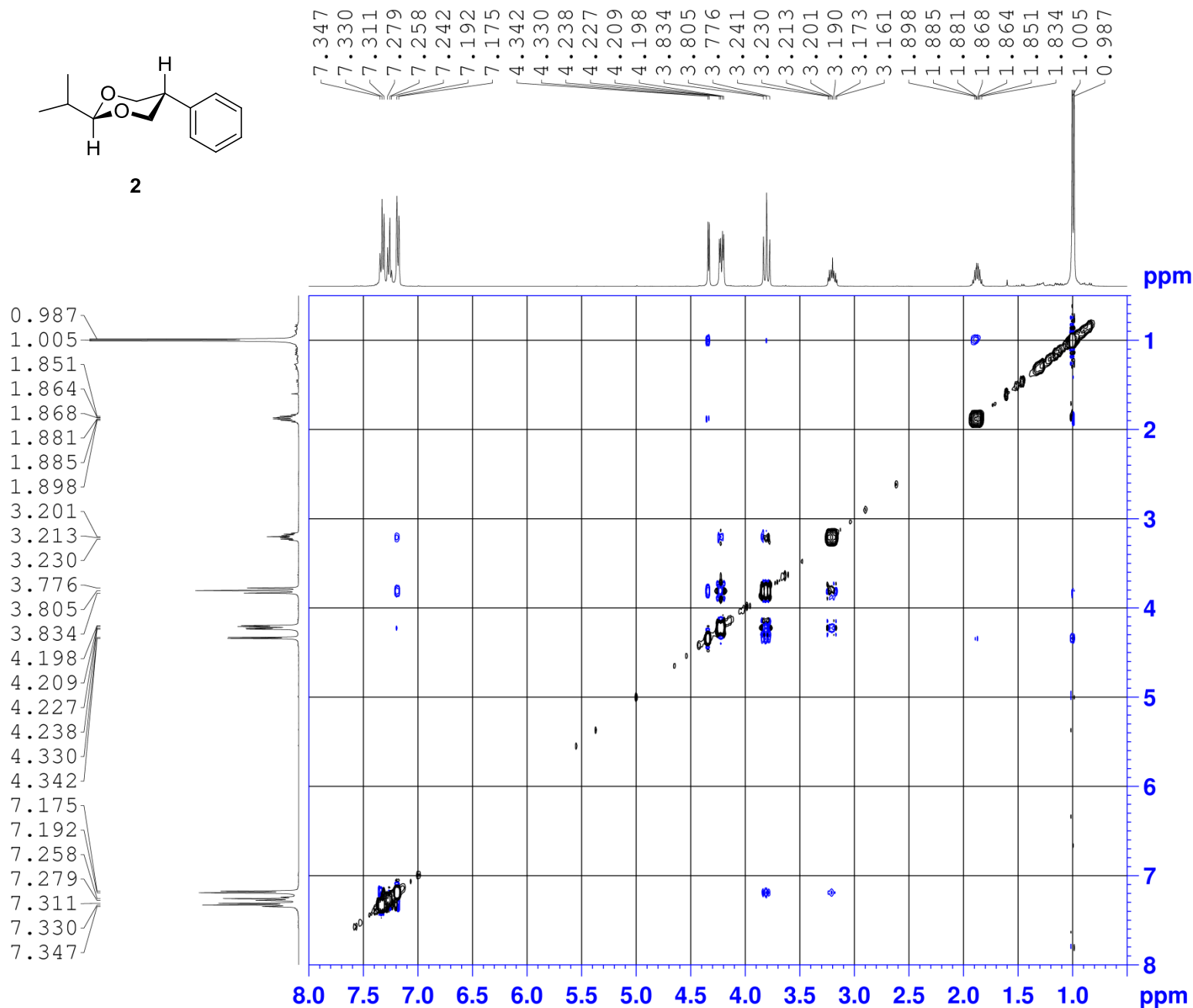


2





2



Current Data Parameters
NAME kl-2-88-eq Phenyl&3F - H1Nesyp
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20141212
Time 19.44
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesypphpgp
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 80.6
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
INO 0.00024480 sec

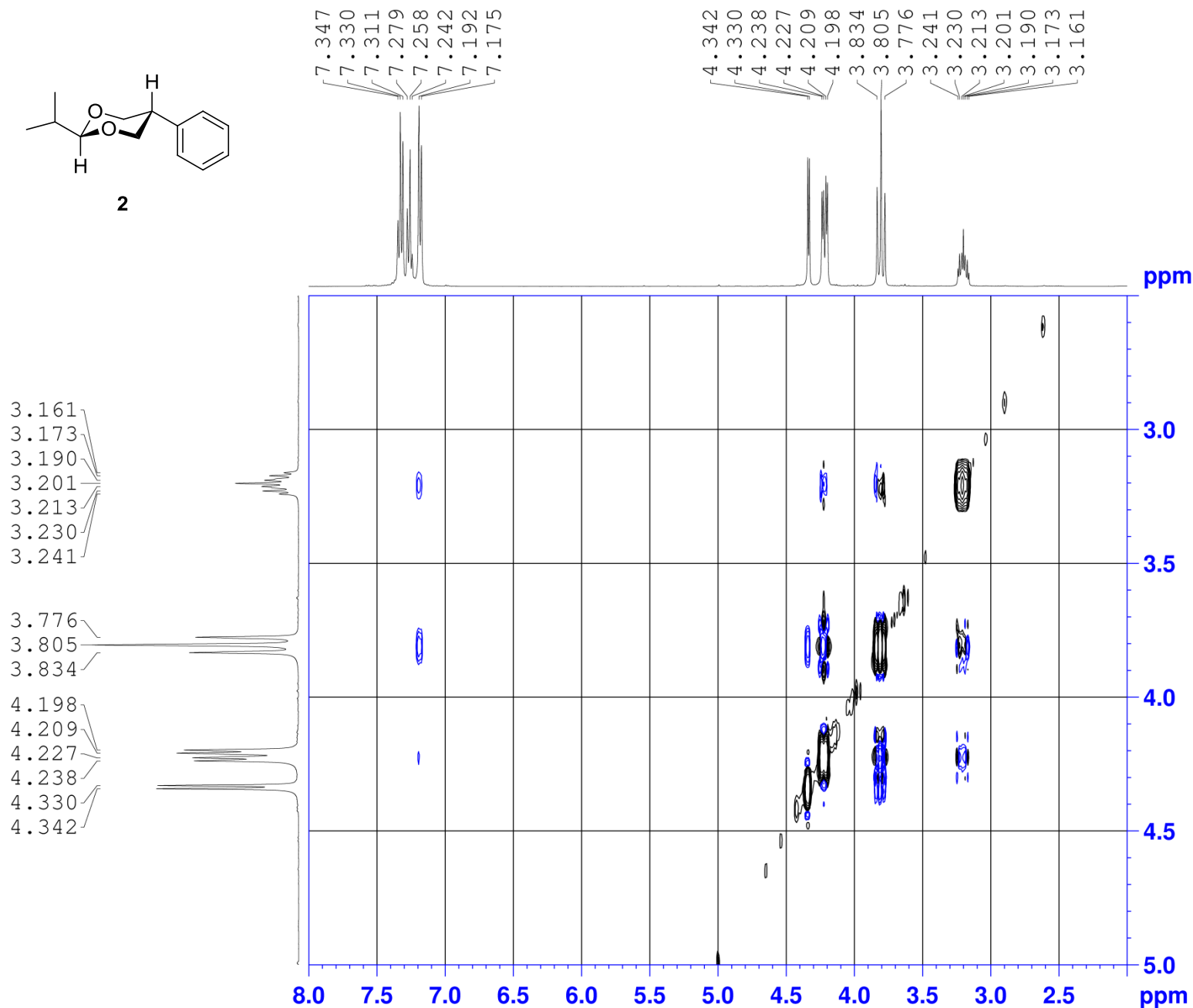
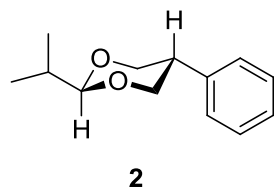
===== CHANNEL f1 =====
SF01 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SF01 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440063 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440060 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0



Current Data Parameters
 NAME kl-2-88-eq Phenyl&3F - H1NoesyP
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20141212
 Time 19.44
 INSTRUM spect
 PROBHD 5 mm PABBO BB/
 PULPROG noesypphpgp
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 32
 SWH 4084.967 Hz
 FIDRES 1.994613 Hz
 AQ 0.2506752 sec
 RG 80.6
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 D0 0.00010330 sec
 D1 2.00000000 sec
 D8 0.699999999 sec
 D11 0.030000000 sec
 D12 0.000020000 sec
 D16 0.000200000 sec
 INO 0.00024480 sec

----- CHANNEL f1 -----
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.00 usec
 P2 30.00 usec
 P17 2500.00 usec
 PLW1 12.00000000 W
 PLW10 3.99410009 W

----- GRADIENT CHANNEL -----
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FnmODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440063 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440060 MHz
 WDW
 SSB 2
 LB 0 Hz
 GB 0



Current Data Parameters
NAME kl-2-88-eq Phenyl¹³C
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20141212
Time 20.40
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG hsqcetdetsps1p2.3
TD 1024
SOLVENT CDCl₃
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNST2 145.000000
CNST17 -0.5000000
D0 0.00000300 sec
D1 1.50000000 sec
D4 0.00172414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.00360000 sec
D24 0.00089000 sec
INO 0.00003010 sec

===== CHANNEL f1 =====
SFO1 400.1458807 MHz
NUC1 ¹H
P1 15.25 usec
P2 30.50 usec
P28 1000.00 usec
PLW1 12.00000000 W

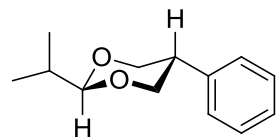
===== CHANNEL f2 =====
SFO2 100.6233320 MHz
NUC2 ¹³C
CPDPRG2 bl_p5m4sp_4sp.2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1900.00 usec
P63 1500.00 usec
PLW0 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SPOAL3 0.500
SPOFFS3 0 Hz
SPW3 7.63940001 W
SPNAM[7] Crp60comp.4
SPOAL7 0.500
SPOFFS7 0 Hz
SPW7 7.63940001 W
SPNAM[14] Crp32,1.5,20.2
SPOAL14 0.500
SPOFFS14 0 Hz
SPW14 3.25950003 W
SPNAM[18] Crp60_kfilt.2
SPOAL18 0.500
SPOFFS18 0 Hz
SPW18 1.83050001 W
SPNAM[31] Crp32,1.5,20.2
SPOAL31 0.500
SPOFFS31 0 Hz
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPNAM[3] SMSQ10.100
GPNAM[4] SMSQ10.100
GP21 80.00 %
GP22 20.10 %
GP23 11.00 %
GP24 5.00 %
P16 1000.00 usec
P19 600.00 usec

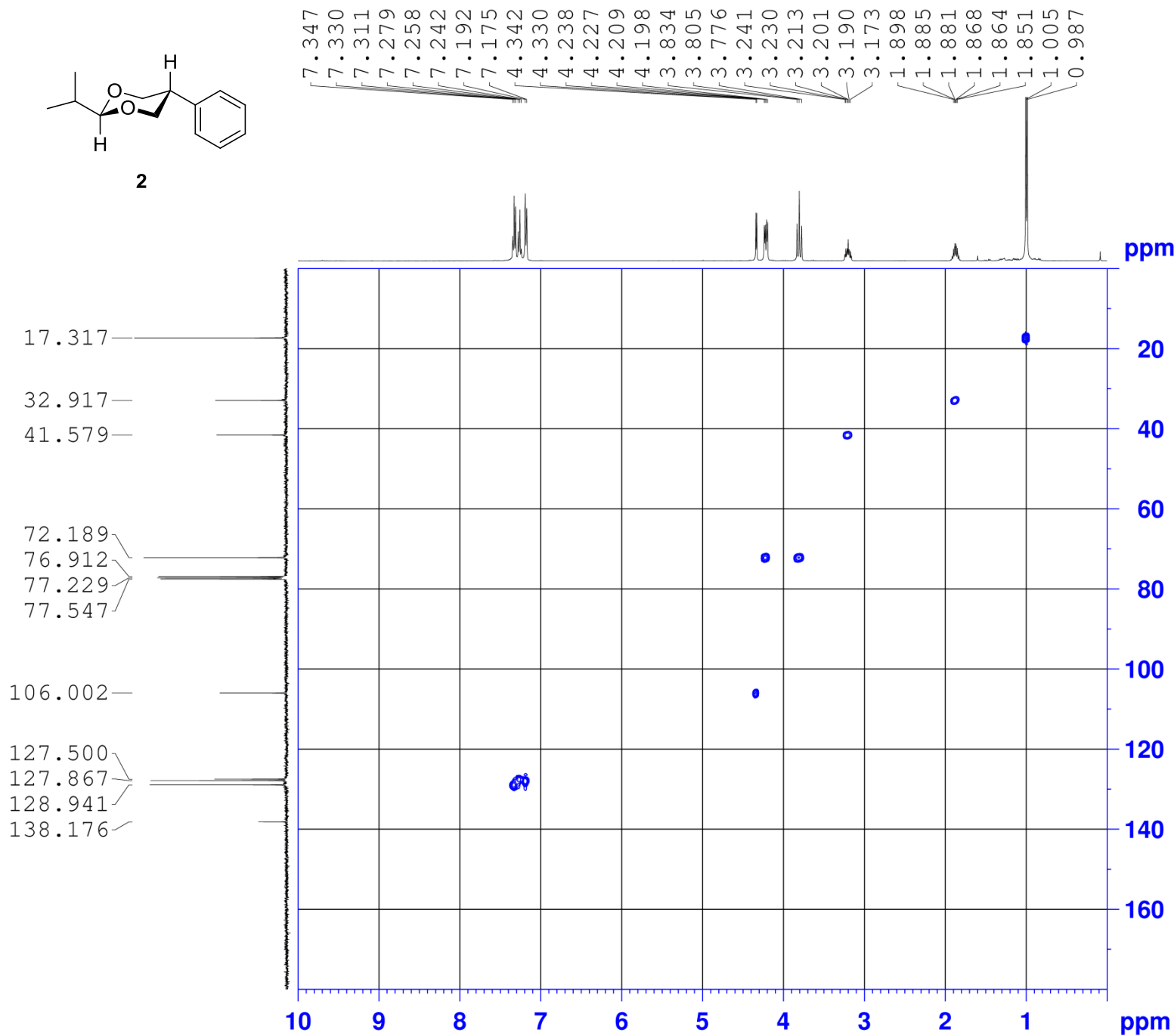
F1 - Acquisition parameters
TD 128
SFO1 100.6233 MHz
FIDRES 129.775742 Hz
SW 165.084 ppm
FnMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440047 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162637 MHz
WDW States
SSB 2
LB 0 Hz
GB 0



2



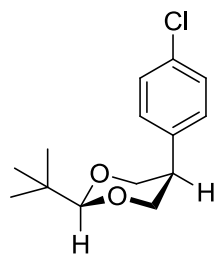


Current Data Parameters
NAME kl-2-171-lowerspot-H1
EXPNO 1
PROCNO 1

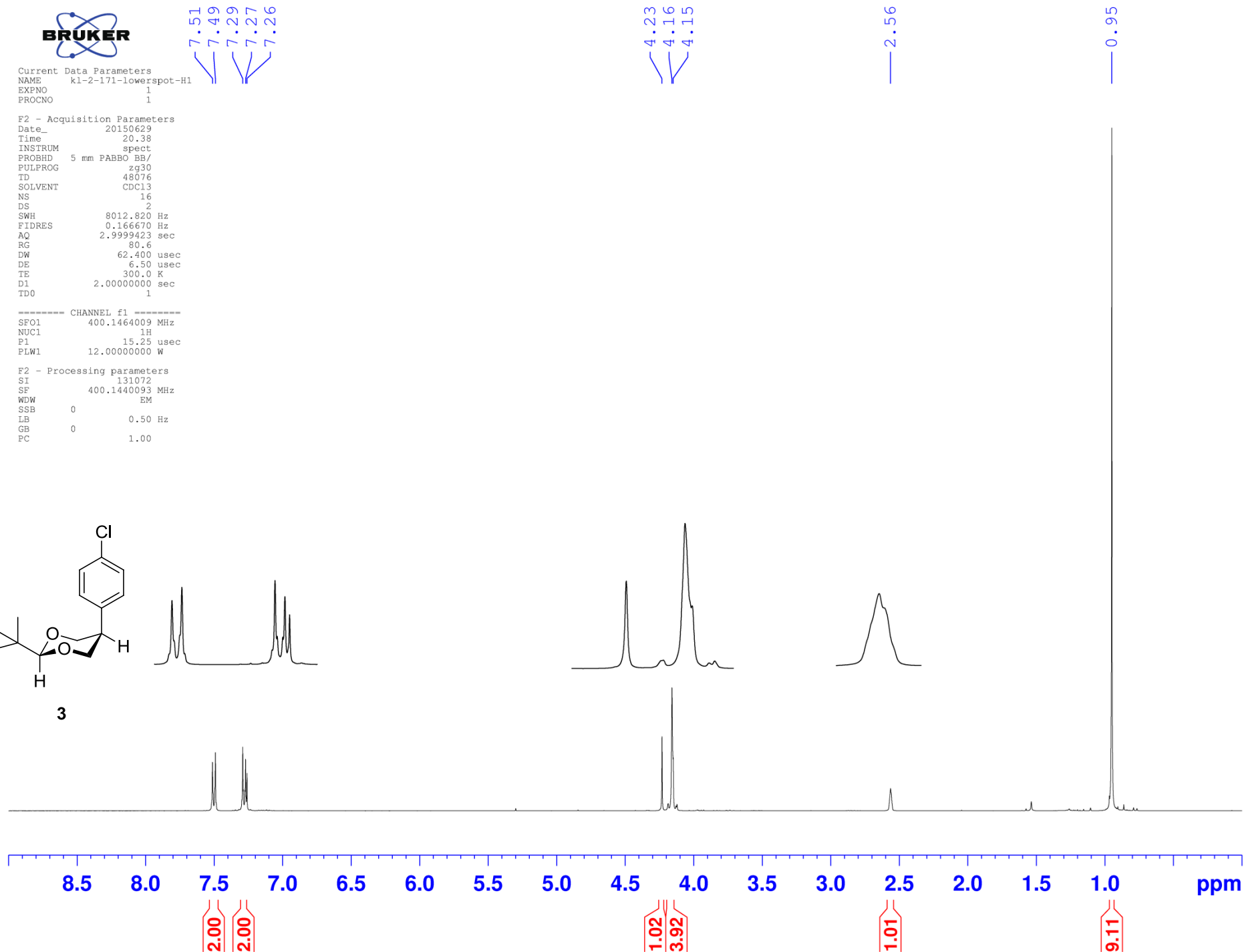
F2 - Acquisition Parameters
Date_ 20150629
Time_ 20.38
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 80.6
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440093 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00



3





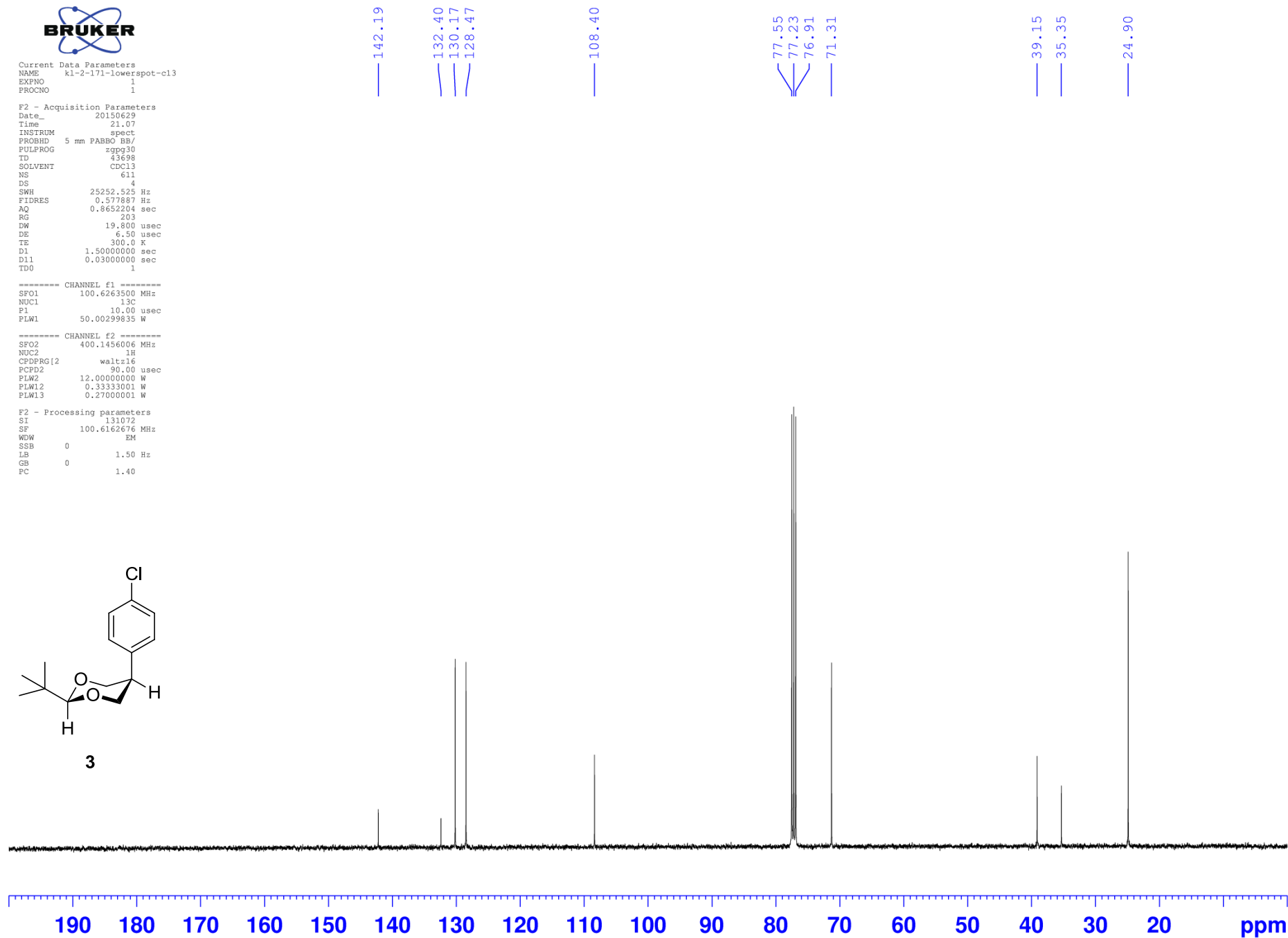
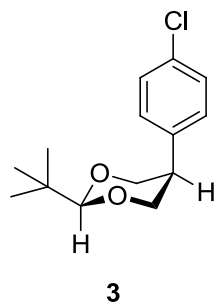
Current Data Parameters
NAME kl-2-171-lowerspot-cl3
EXPNO 1
PROCNO 1

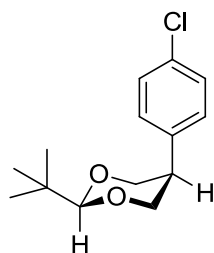
F2 - Acquisition Parameters
Date_ 20150629
Time 21.07
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 611
DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
AQ 0.8652204 sec
RG 203
DW 19.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

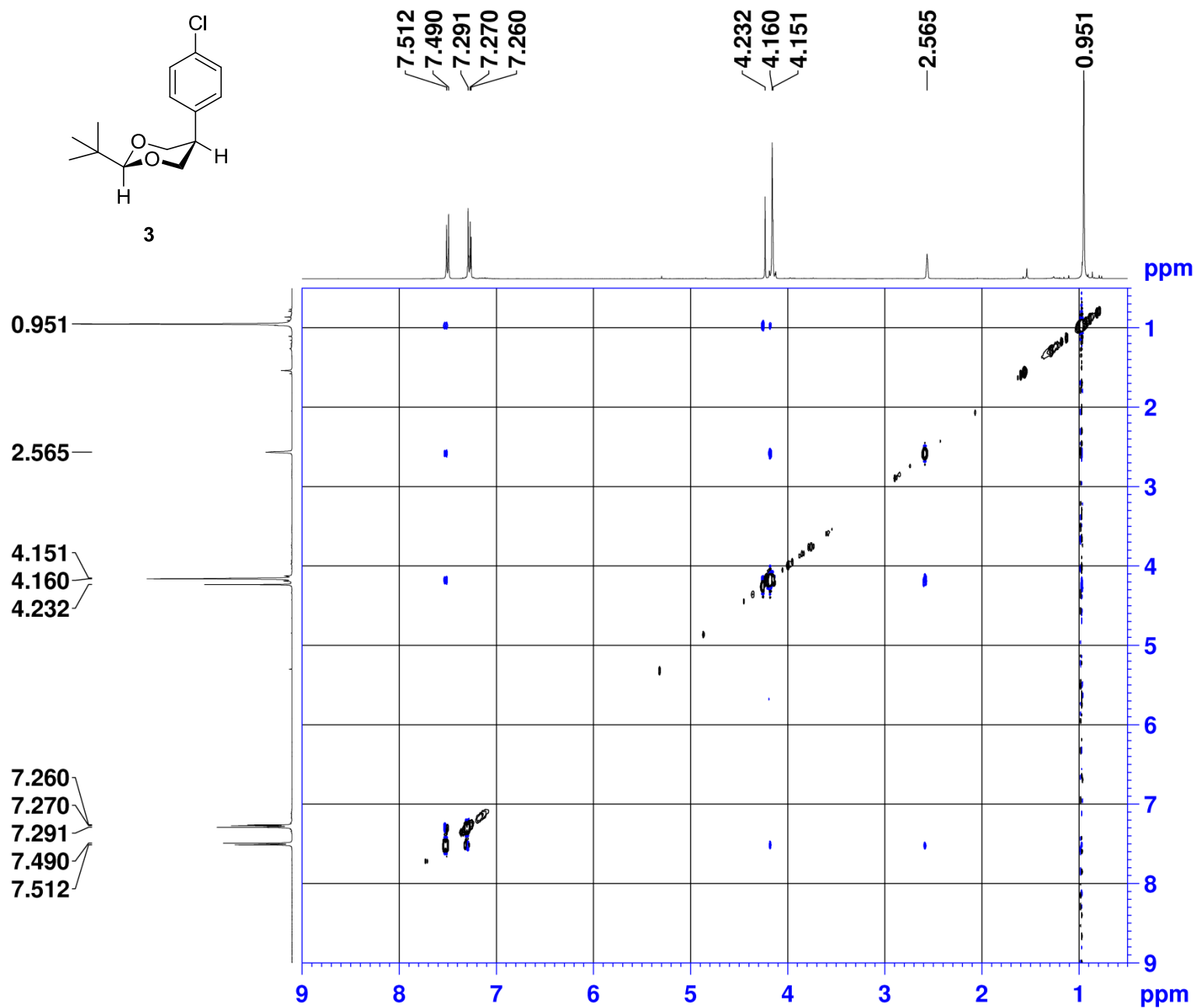
===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162676 MHz
WDW EM
SSB 0
LB 1.50 Hz
GB 0
PC 1.40





3



Current Data Parameters
NAME kl-2-171-lowerspot-HOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150629
Time 21.33
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphpp
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

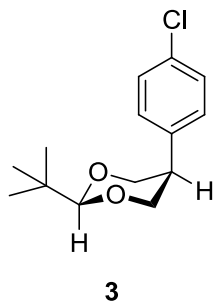
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440000 MHz
WDW
SSB 2
LB 0 Hz
GB 0



7.512
7.490
7.291
7.270
7.260



Current Data Parameters
NAME kl-2-171-lowerspot-HNOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150629
Time 21.33
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphpp
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

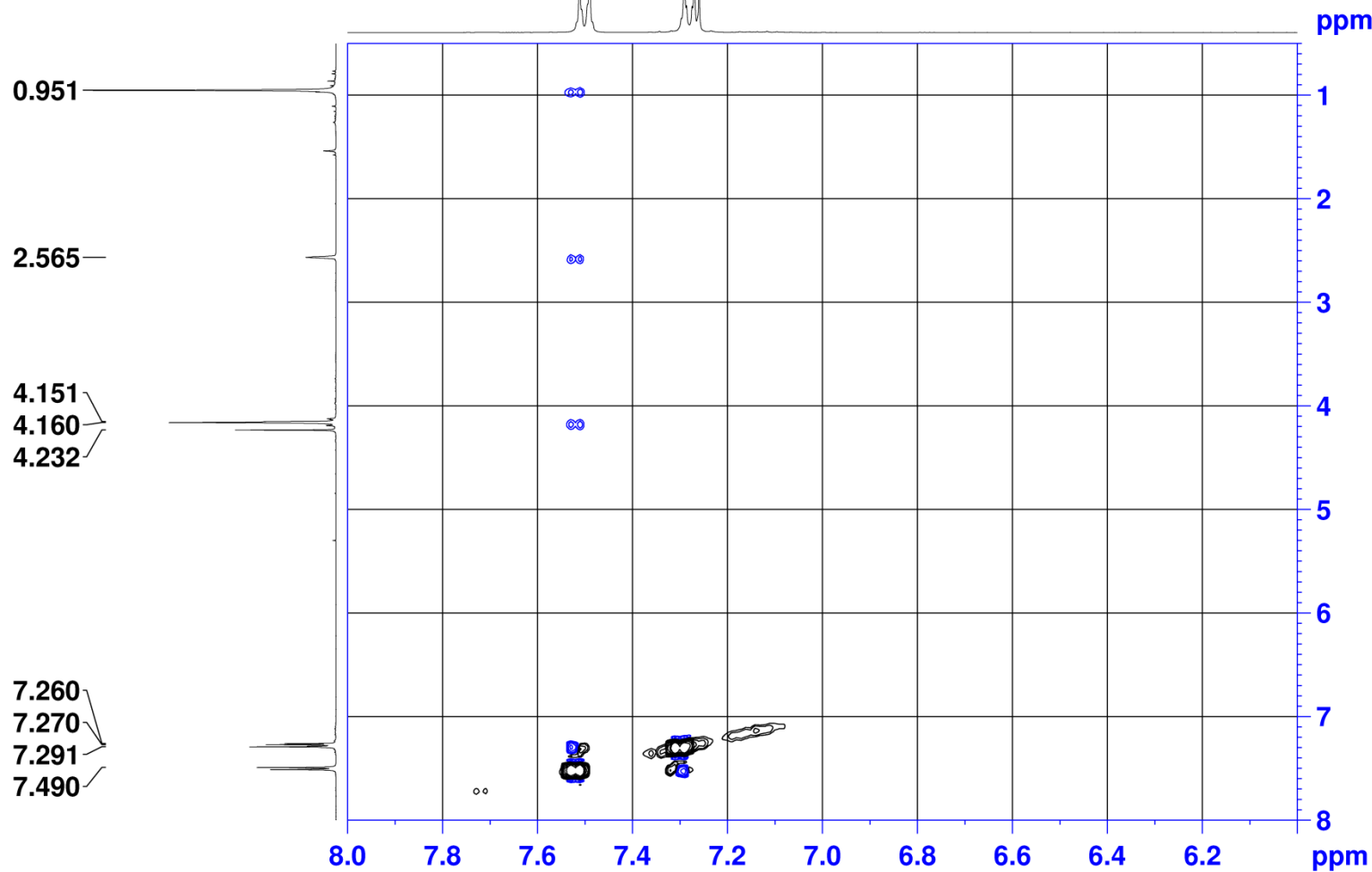
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

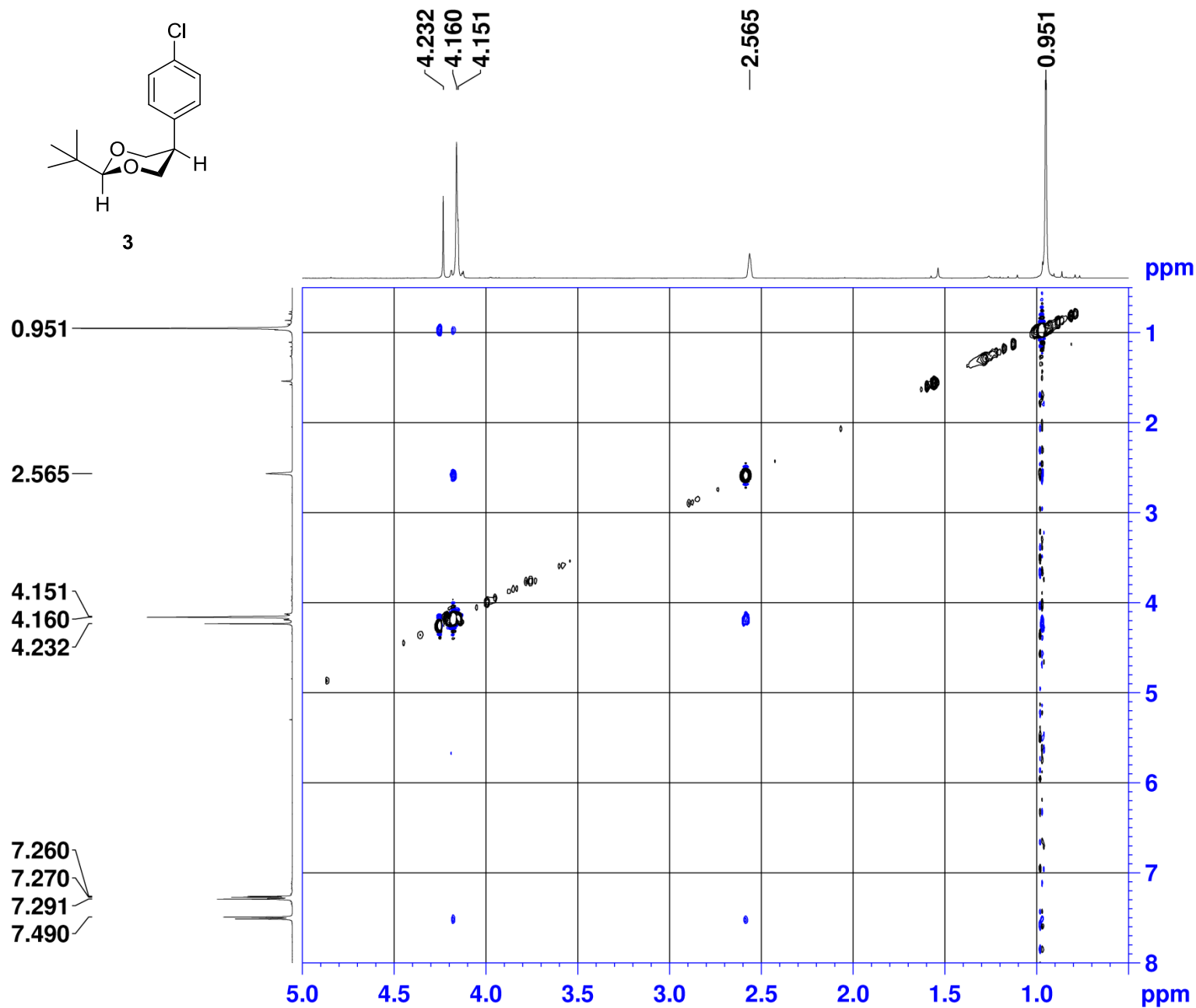
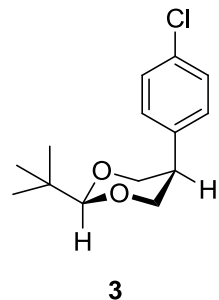
===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440000 MHz
WDW
SSB 2
LB 0 Hz
GB 0





Current Data Parameters
 NAME kl-2-171-lowerspot-HNOESY
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20150629
 Time 21.33
 INSTRUM spect
 PROBHD 5 mm PABBO BB/
 PULPROG noesygpph
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 32
 SWH 4084.967 Hz
 FIDRES 1.994613 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 D0 0.00010330 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec

===== CHANNEL f1 =====
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.00 usec
 P2 30.00 usec
 P17 2500.00 usec
 PLW1 12.00000000 W
 PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FMODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440000 MHz
 WDW
 SSB 2
 LB 0 Hz
 GB 0



Current Data Parameters
NAME kl-2-171-lowerspot-HSQC
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150629
Time 21.12
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG hsqcetdetspsisp2.3
TD 1024
SOLVENT CDCl3
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNS2 145.000000
CNS17 -0.5000000
D0 0.00000300 sec
D1 1.50000000 sec
D4 0.00172414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.00360000 sec
D24 0.00089000 sec
INO 0.00003010 sec

===== CHANNEL f1 =====
SFO1 400.1458807 MHz
NUC1 1H
P1 15.25 usec
P2 30.50 usec
P28 1000.00 usec
PLW1 12.00000000 W

===== CHANNEL f2 =====
SFO2 100.6233320 MHz
NUC2 13C
CPDPRG2 2 bl_p5m4sp_4sp.2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1900.00 usec
P63 1500.00 usec

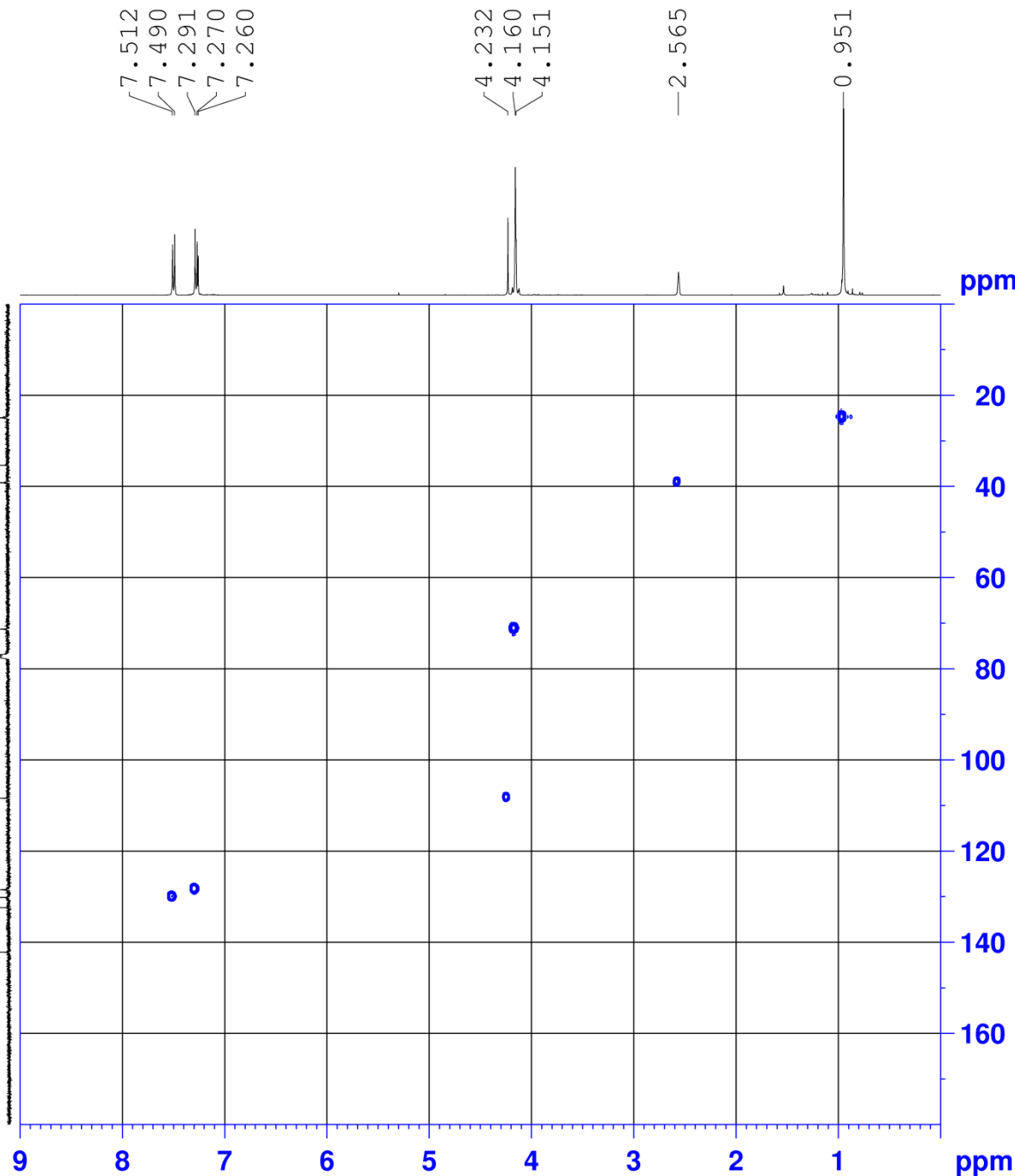
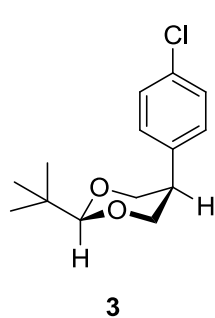
PLW0 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SFO13 0.500
SPOFFS3 0 Hz
SPW3 7.63940001 W
SPNAM[7] Crp60comp.4
SFOAL7 0.500
SPOFFS7 0 Hz
SPW7 7.63940001 W
SPNAM[14] Crp32,1.5,20.2
SFOAL14 0.500
SPOFFS14 0 Hz
SPW14 3.25950003 W
SPNAM[18] Crp60_kfilt.2
SFOAL18 0.500
SPOFFS18 0 Hz
SPW18 1.83050001 W
SPNAM[31] Crp32,1.5,20.2
SFOAL31 0.500
SPOFFS31 0 Hz
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPNAM[3] SMSQ10.100
GPNAM[4] SMSQ10.100
GPZ1 80.00 %
GPZ2 20.10 %
GPZ3 11.00 %
GPZ4 5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 128
SFO1 100.6233 MHz
FIDRES 129.775742 Hz
SW 165.084 ppm
FnMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162890 MHz
WDW
SSB 2
LB 0 Hz
GB 0





Current Data Parameters
NAME kl-2-171-topspot-H1
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150629
Time 22.33
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 40.3
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

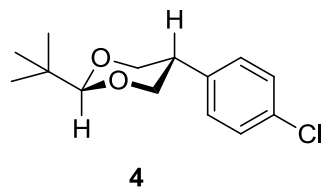
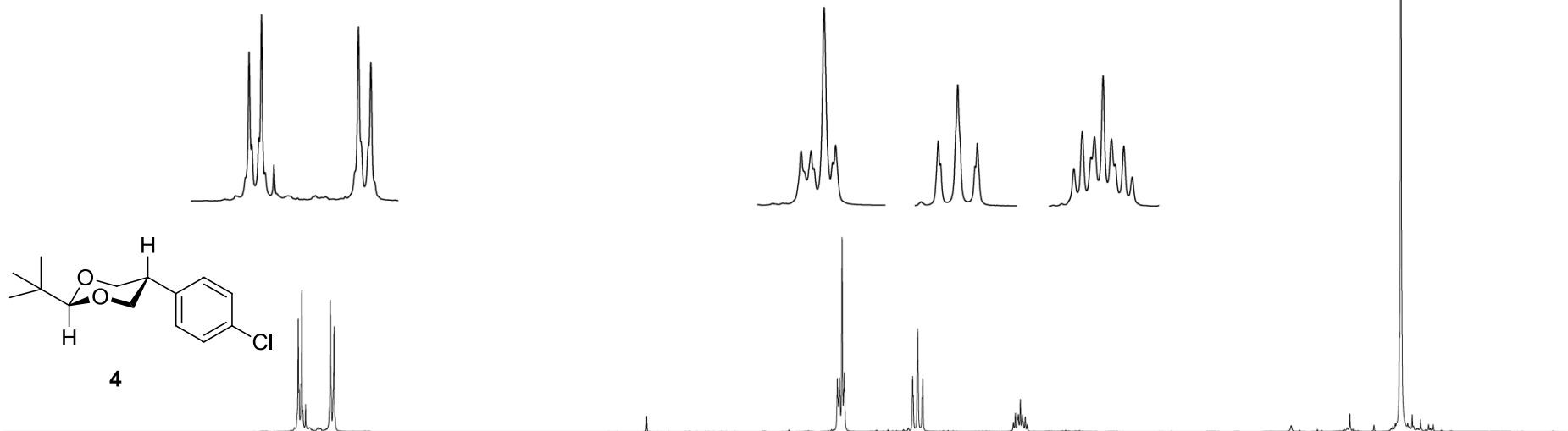
===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440097 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00

7.30
7.28
7.26
7.12
7.10

4.20
4.19
4.18
4.17
4.16
4.16
3.77
3.76
3.74
3.71
3.71
3.19
3.17
3.16
3.16
3.15
3.13
3.13
3.12
3.11

0.96



8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 ppm

2.00
2.00

3.01

2.01

1.00

8.99



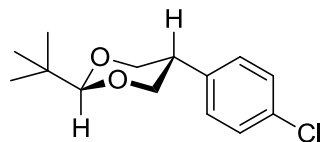
Current Data Parameters
NAME kl-2-171-topspot-cl3
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150629
Time 22.42
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 75
DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
AQ 0.8652204 sec
RG 203
DW 19.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

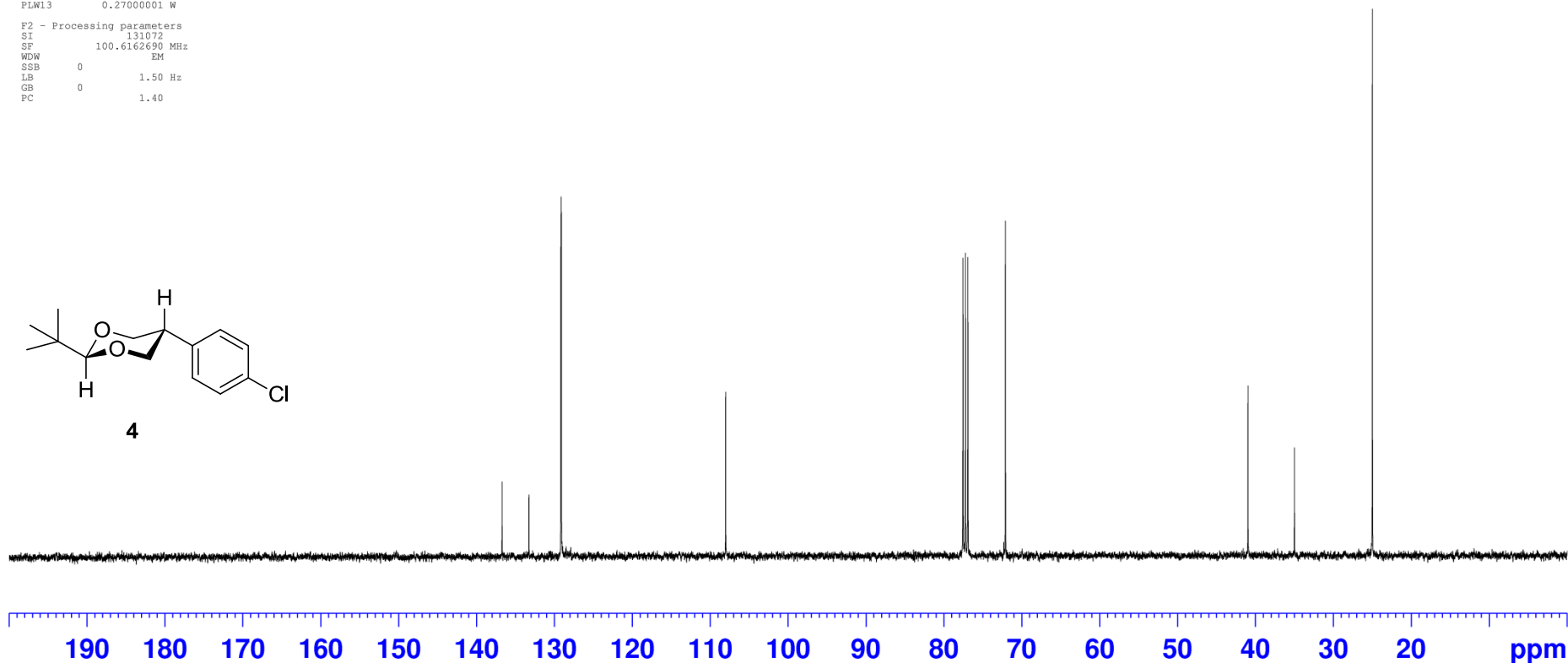
===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162690 MHz
WDW EM
SSB 0
LB 1.50 Hz
GB 0
PC 1.40



4

136.72
133.26
129.16
129.11
108.01
77.55
77.23
76.91
72.10
40.99
35.03
25.00





Current Data Parameters
NAME kl-2-171-topspot-HNOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150629
Time 23.16
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphph
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 80.6
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

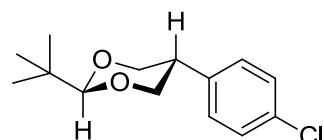
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

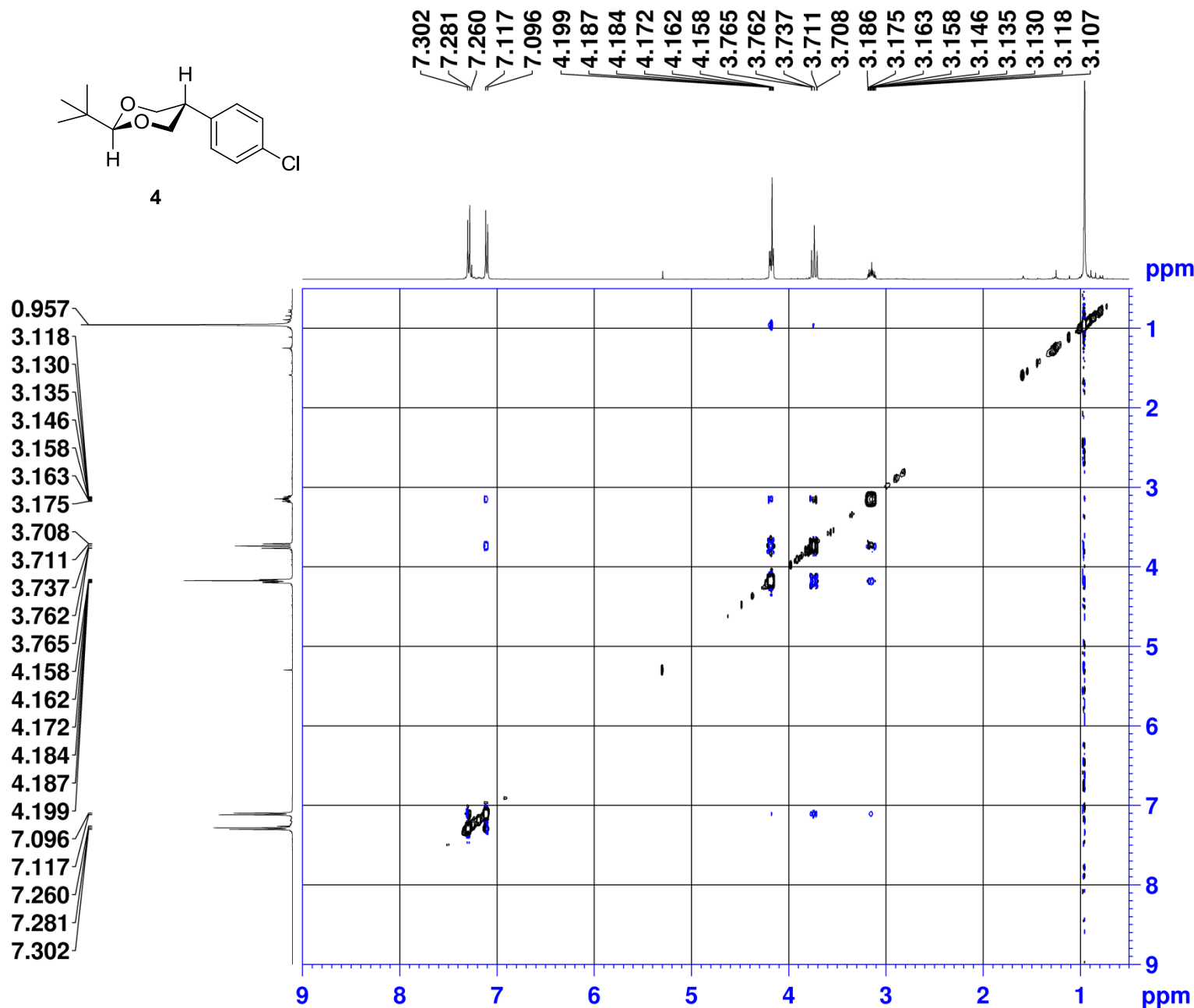
F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

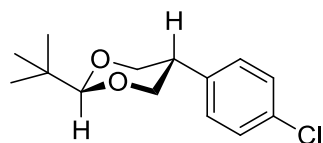
F2 - Processing parameters
SI 1024
SF 400.1440066 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440082 MHz
WDW
SSB 2
LB 0 Hz
GB 0



4





4

7.302
7.281
7.260
7.117
7.096



Current Data Parameters
NAME kl-2-171-topspot-HNOSY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150629
Time 23.16
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphpp
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 80.6
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

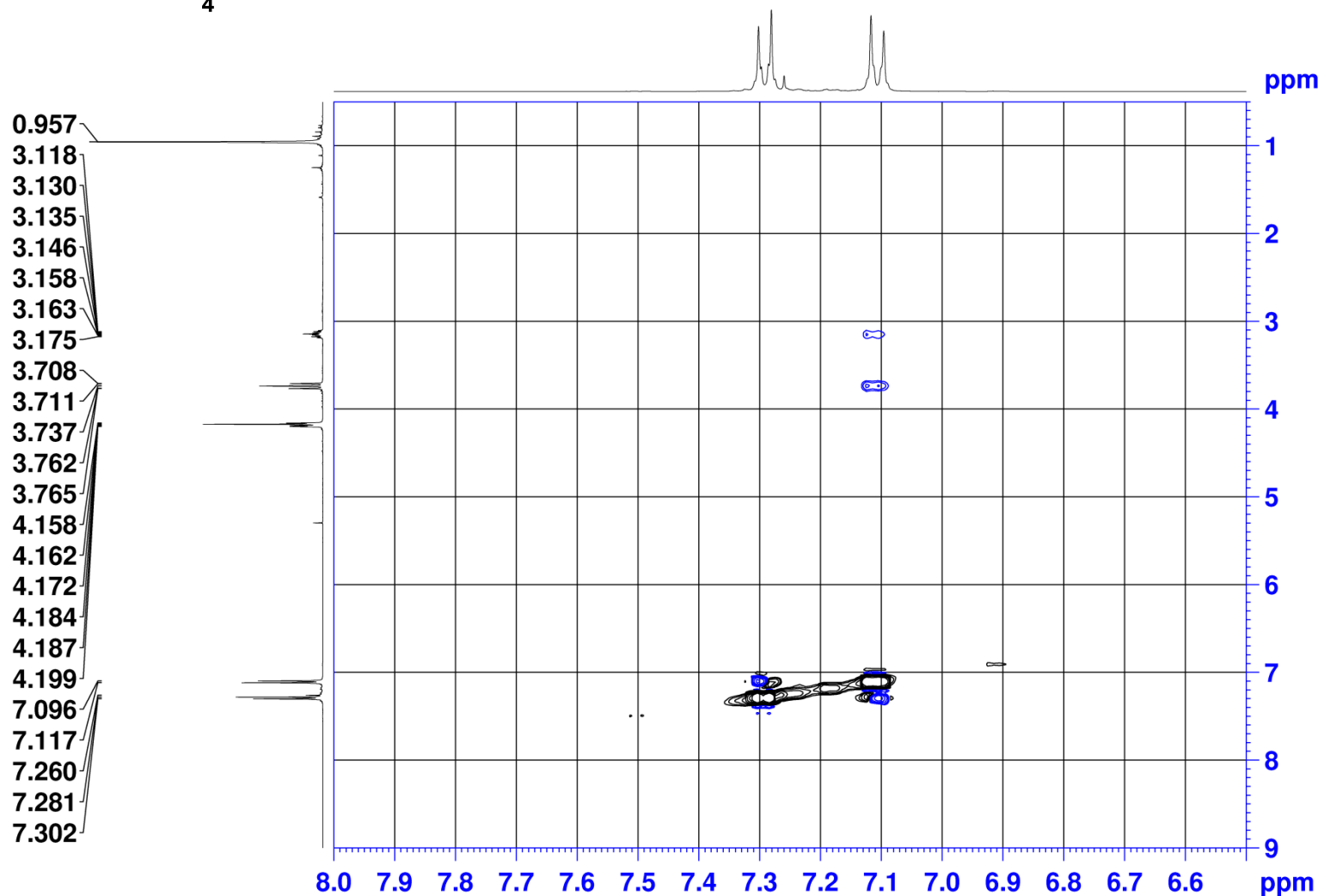
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

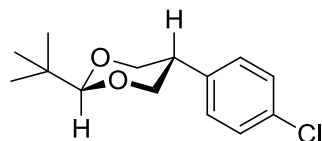
===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440066 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440082 MHz
WDW
SSB 2
LB 0 Hz
GB 0





4

4.187
4.184
4.172
4.162
4.158
3.765
3.762
3.737
3.711
3.708
3.186
3.175
3.163
3.158
3.146
3.135
3.130
3.118
3.107

0.957

0.957
3.118
3.130
3.135
3.146
3.158
3.163
3.175
3.708
3.711
3.737
3.762
3.765
4.158
4.162
4.172
4.184
4.187
4.199
7.096
7.117
7.260
7.281
7.302

5.0

4.5

4.0

3.5

3.0

2.5

2.0

1.5

1.0

ppm

ppm

1

2

3

4

5

6

7

8

9



Current Data Parameters
NAME kl-2-171-topspot-HNOSY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150629
Time 23.16
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphpp
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 80.6
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

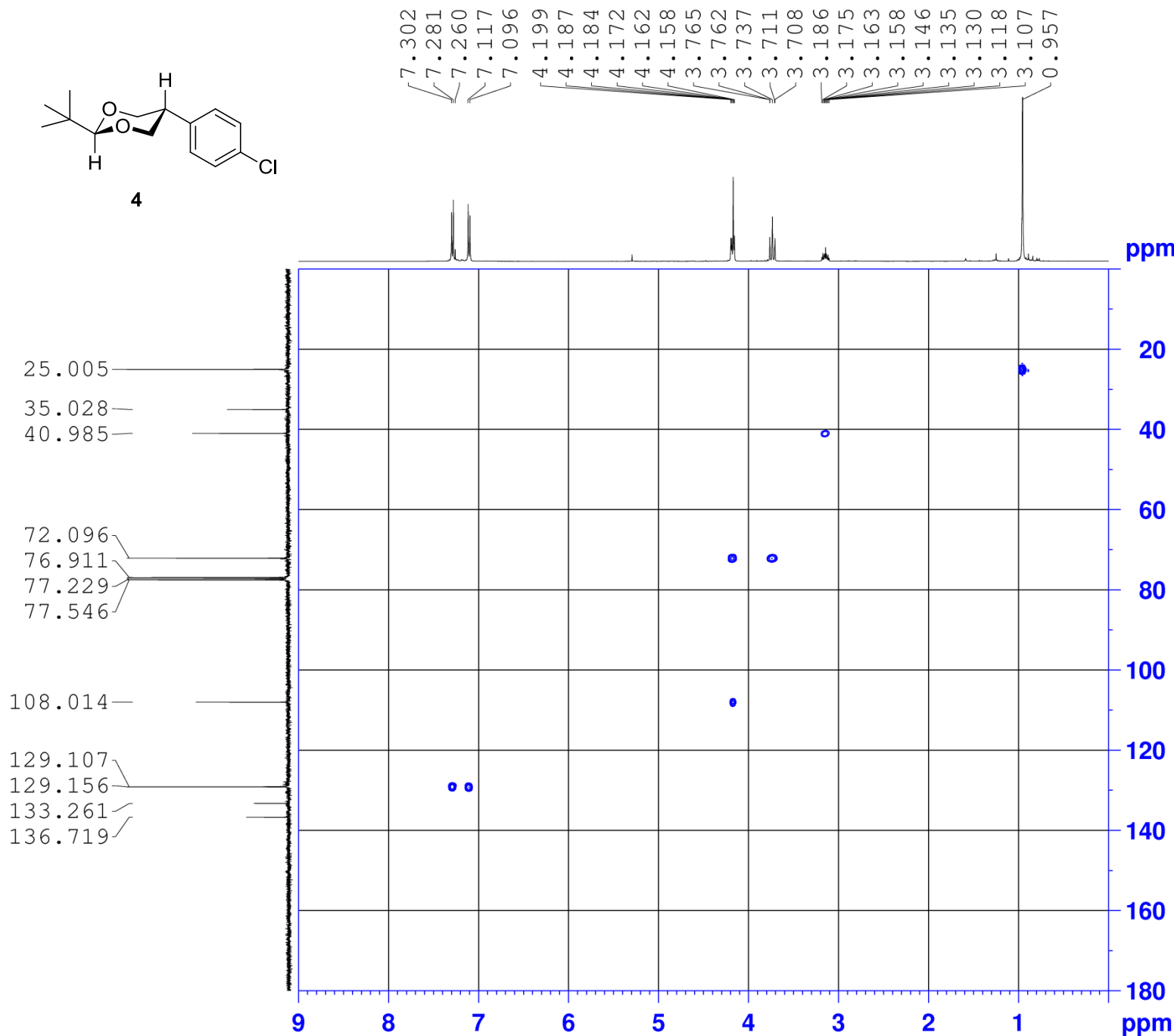
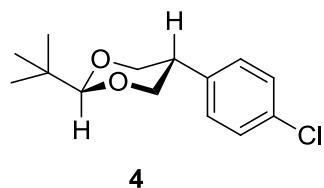
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440066 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440082 MHz
WDW
SSB 2
LB 0 Hz
GB 0



Current Data Parameters
NAME kl-2-171-topspot-HSQC
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150629
Time 22.44
INSTRUM spect
PROBHD 5 mm PABBO BB
PULPROG hsqcetdetspsisp2.3
TD 1024
SOLVENT CDCl3
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNS2 145.000000
CNS17 -0.5000000
D0 0.00000300 sec
D1 1.50000000 sec
D4 0.00172414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.00360000 sec
D24 0.00089000 sec
INO 0.00003010 sec

===== CHANNEL f1 =====
SFO1 400.1458807 MHz
NUC1 1H
P1 15.25 usec
P2 30.50 usec
P28 1000.00 usec
PLW1 12.00000000 W

===== CHANNEL f2 =====
SFO2 100.6233320 MHz
NUC2 13C
CPDPRG2 bl_p5m4sp_4sp.2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1900.00 usec
P63 1500.00 usec

PLW0 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SFO13 0.500
SPOFFS3 0 Hz
SPW3 7.63940001 W
SPNAM[7] Crp60comp.4
SFOAL7 0.500
SPOFFS7 0 Hz
SPW7 7.63940001 W
SPNAM[14] Crp32,1.5,20.2
SFOAL14 0.500
SPOFFS14 0 Hz
SPW14 3.25950003 W
SPNAM[18] Crp60_kfilt.2
SFOAL18 0.500
SPOFFS18 0 Hz
SPW18 1.83050001 W
SPNAM[31] Crp32,1.5,20.2
SFOAL31 0.500
SPOFFS31 0 Hz
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPNAM[3] SMSQ10.100
GPNAM[4] SMSQ10.100
GPZ1 80.00 %
GPZ2 20.10 %
GPZ3 11.00 %
GPZ4 5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 128
SFO1 100.6233 MHz
FIDRES 129.775742 Hz
SW 165.084 ppm
FnMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440061 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162566 MHz
WDW States
SSB 2
LB 0 Hz
GB 0

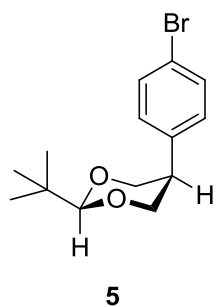


Current Data Parameters
NAME kl-200-H1-axial
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150904
Time 19.30
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 144
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.0000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440098 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00

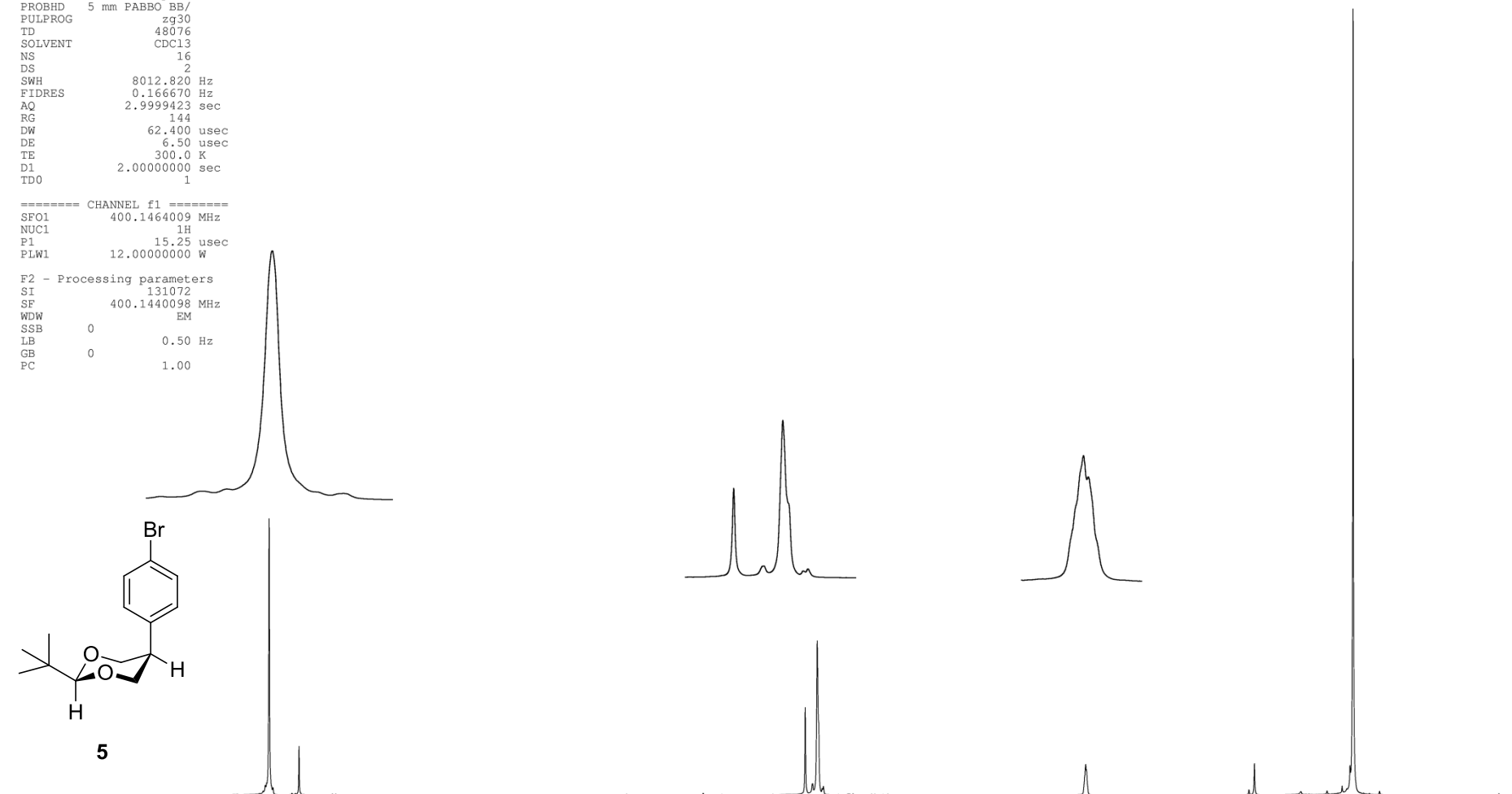


7.46
7.45
7.44
7.42
7.26

4.23
4.18
4.16
4.12

2.55
2.54

0.95



8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0

ppm

4.00

1.03
4.09

1.01

8.99



Current Data Parameters
NAME ki-200-cl3-axial
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150904
Time 19.52
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG udeft
TD 17368
SOLVENT CDCl3
NS 137
DS 0
SWH 24038.461 Hz
FIDRES 1.388864 Hz
AQ 0.3600064 sec
RG 203
DW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 4.00000000 sec
D11 0.03000000 sec
D12 0.00002000 sec
D20 200.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6273568 MHz
NUC1 13C
P1 10.00 usec
P13 2000.00 usec
P26 500.00 usec
PLW1 50.00299835 W
SPNAM[5] Crp60comp,4
SFOAL5 0.500
SPOFFS5 0 Hz
SPW5 7.63990021 W
SPNAM[8] Crp60,0.5,20.1
SFOAL8 0.500
SPOFFS8 0 Hz
SPW8 7.63990021 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CDDPRG[2] waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W

F2 - Processing parameters
SI 131072
SF 100.6162676 MHz
WCHW 8K
SSB 0
LA 2.00 Hz
GB 0
PC 1.40

— 142.71

— 131.44
— 130.58

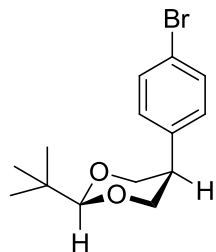
— 120.53

— 108.39

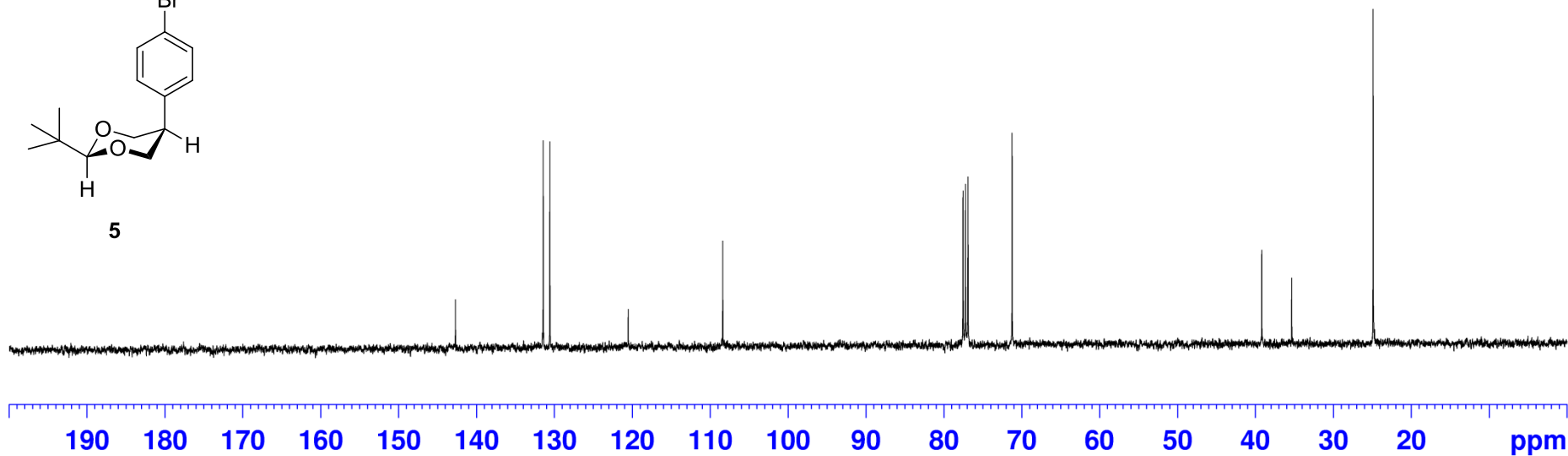
— 77.55
— 77.23
— 76.91
— 71.25

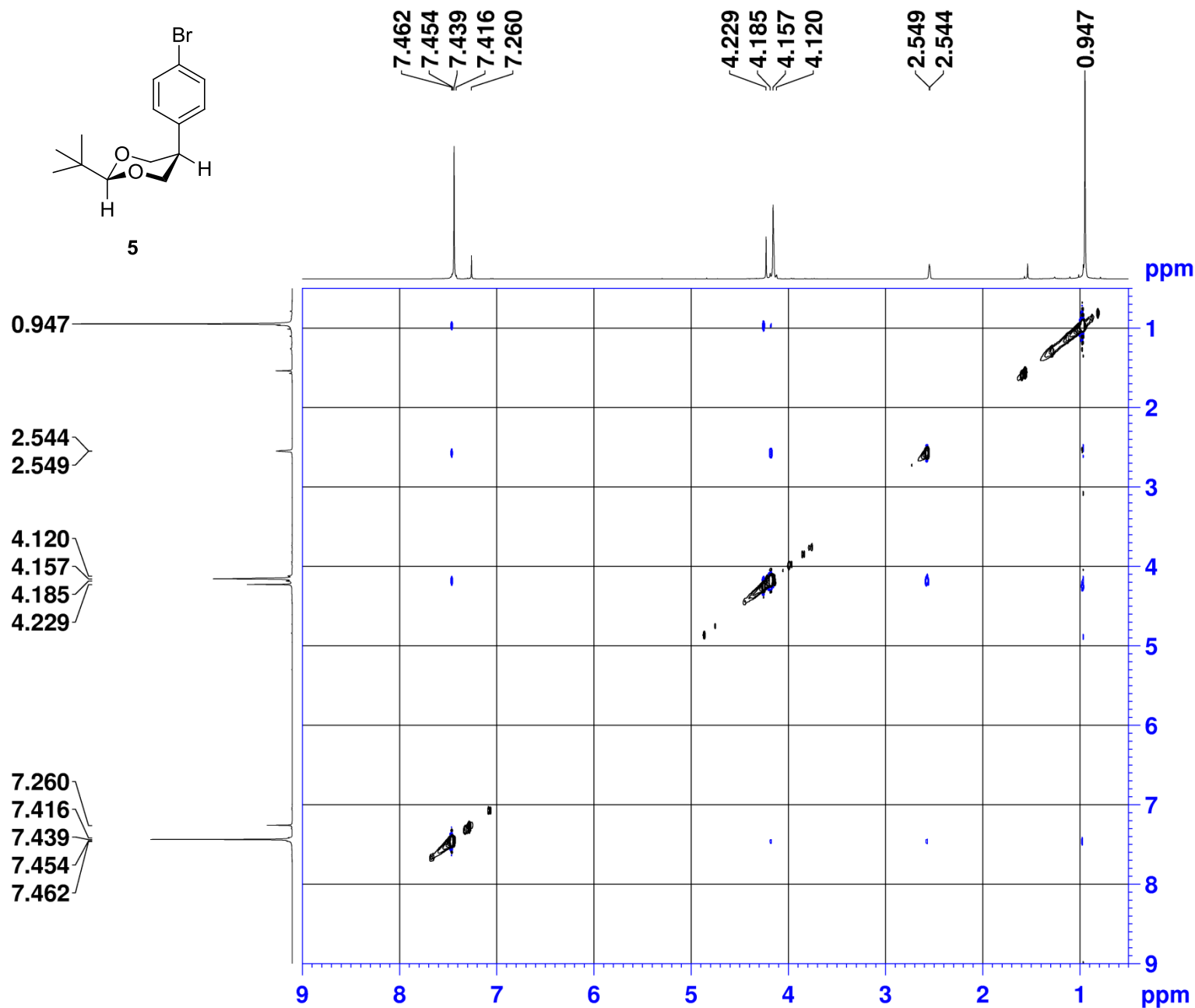
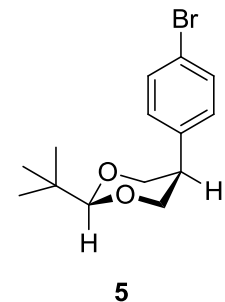
— 39.21
— 35.35

— 24.90



5





Current Data Parameters
 NAME kl-200-HNOESY-axial
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20150904
 Time 20.22
 INSTRUM spect
 PROBHD 5 mm PABBO BB/
 PULPROG noesygpphpp
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 32
 SWH 4084.967 Hz
 FIDRES 1.994613 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 D0 0.00010330 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec

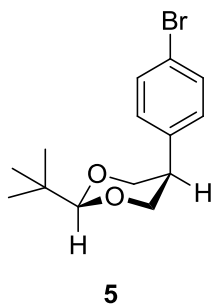
===== CHANNEL f1 =====
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.00 usec
 P2 30.00 usec
 P17 2500.00 usec
 PLW1 12.00000000 W
 PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
 GPNAM[1] SMSQ10.100
 GP21 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FnmODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 FC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440000 MHz
 WDW
 SSB 2
 LB 0 Hz
 GB 0



7.462
7.454
7.439
7.416
7.260



Current Data Parameters
NAME kl-200-HNOESY-axial
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150904
Time 20.22
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphpp
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

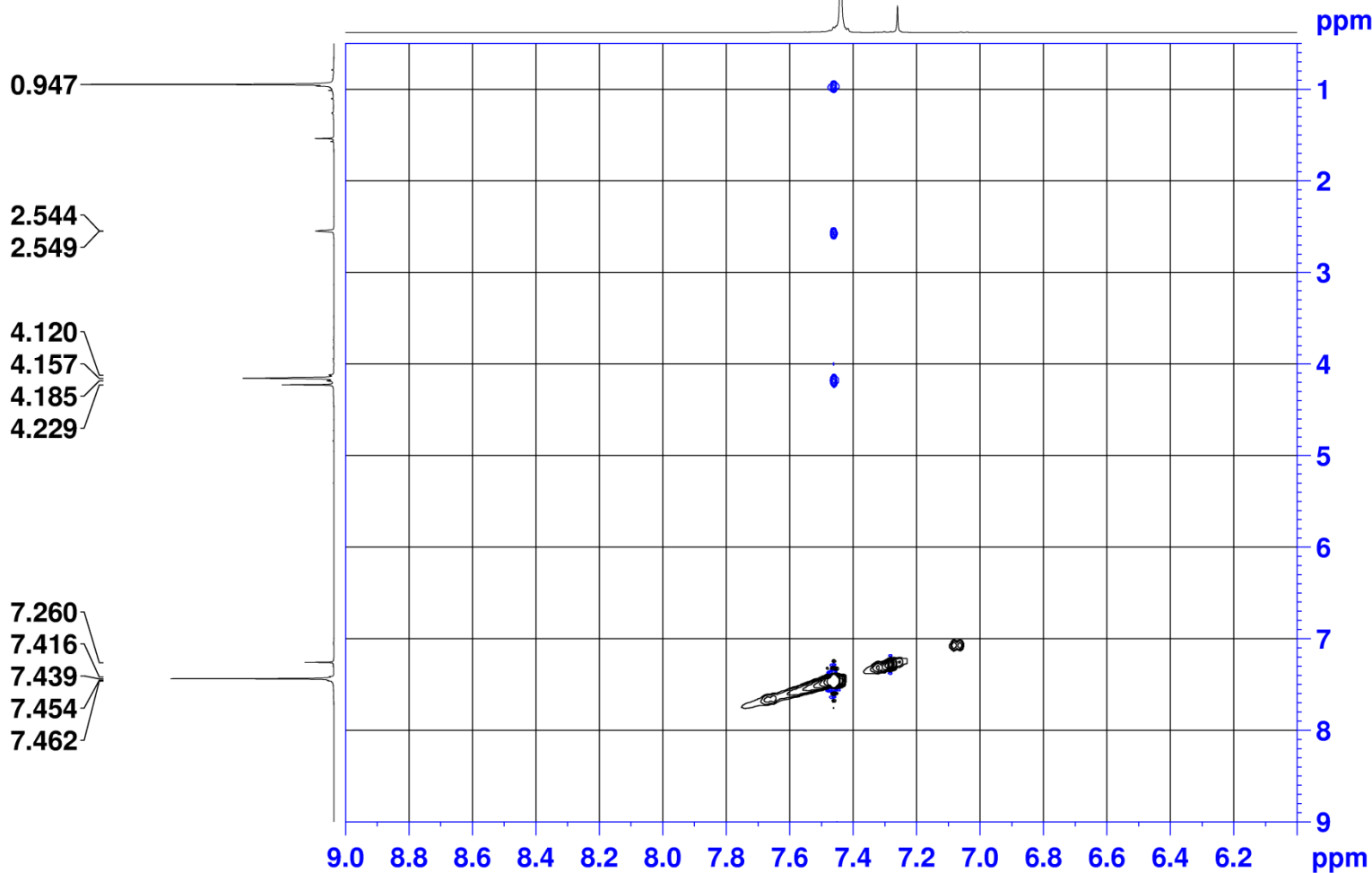
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440000 MHz
WDW
SSB 2
LB 0 Hz
GB 0





Current Data Parameters
NAME kl-200-HNOESY-axial
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150904
Time 20.22
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphpp
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

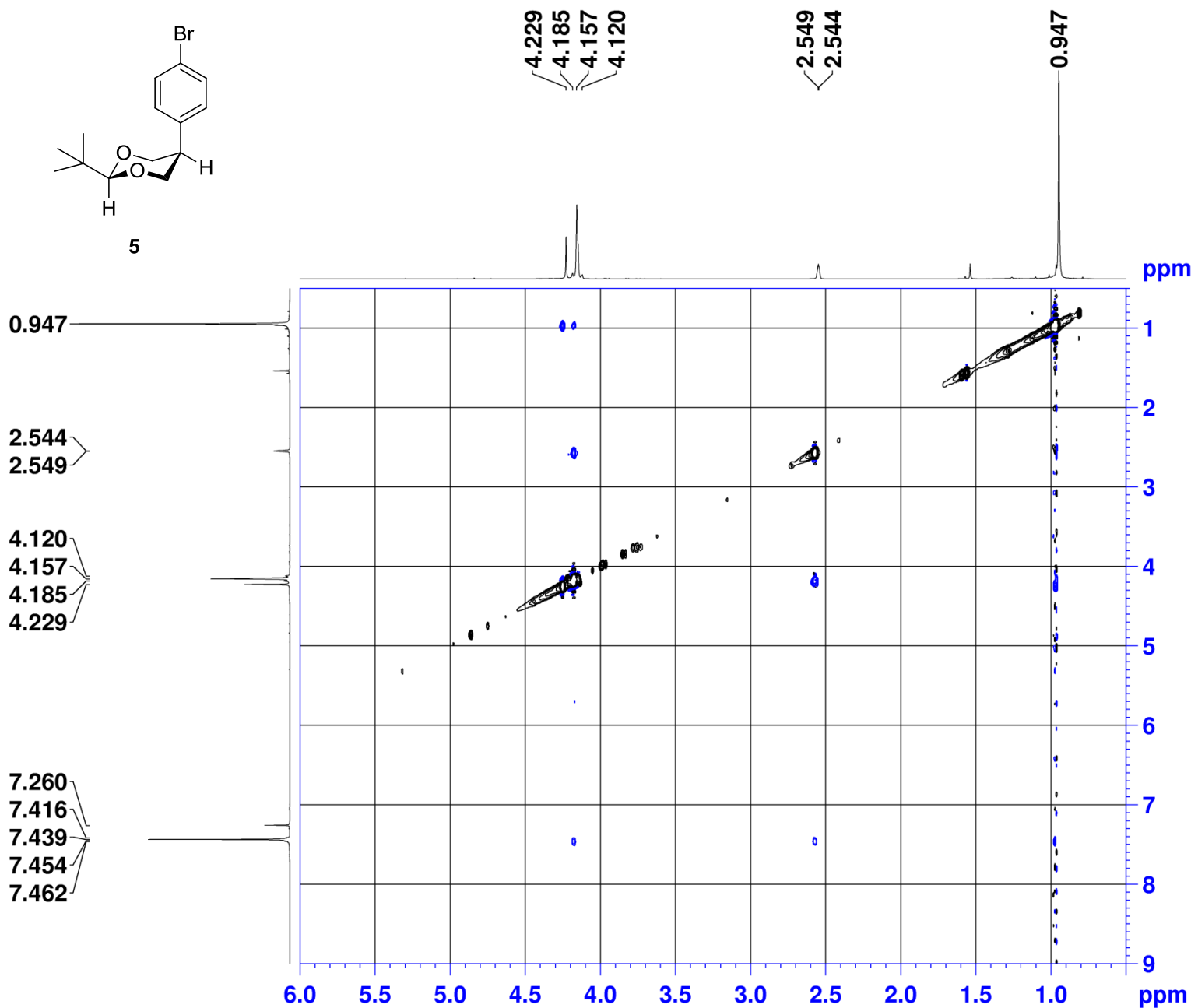
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

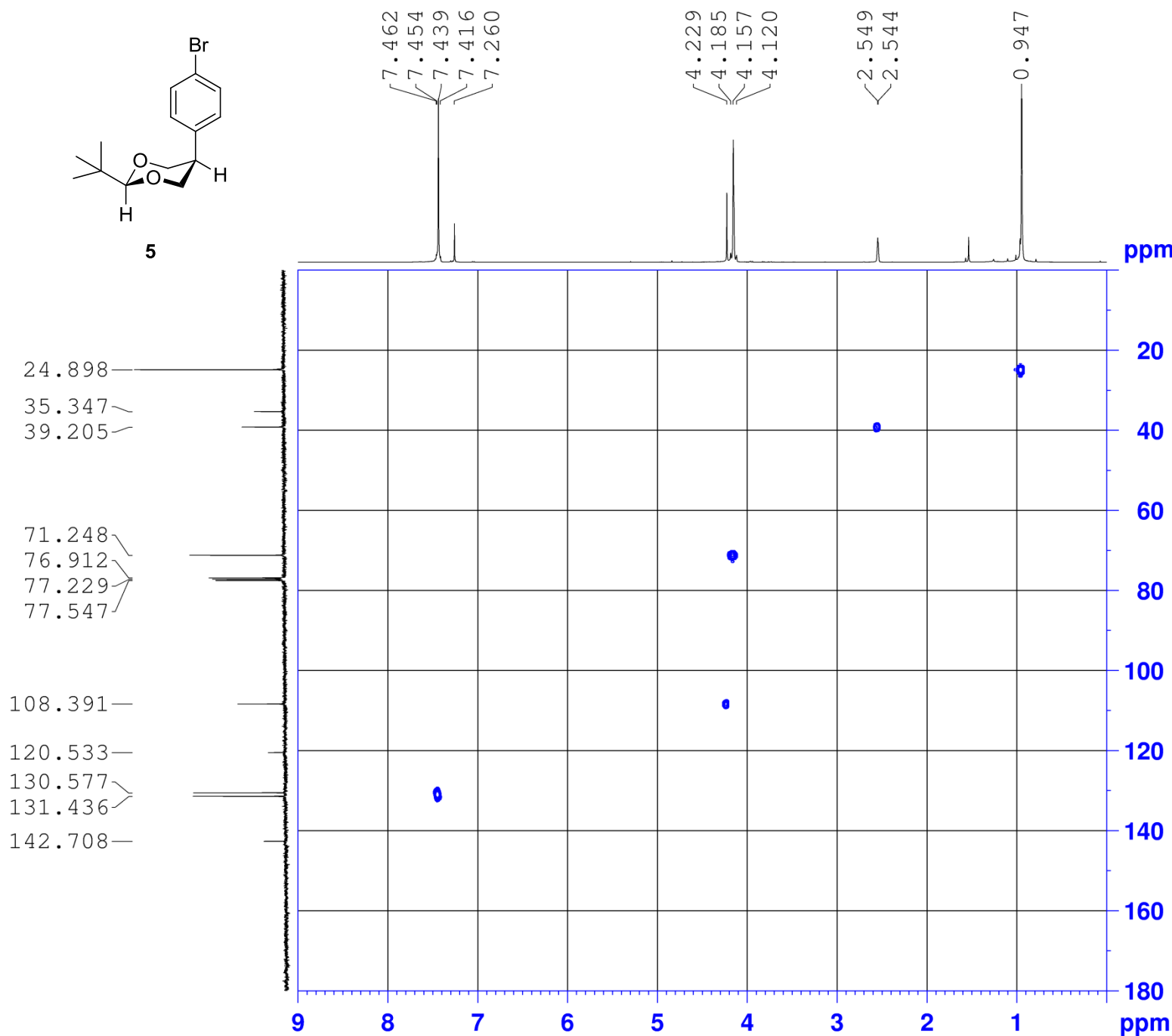
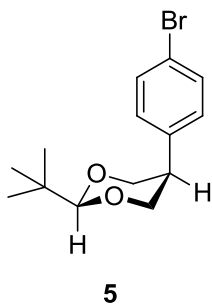
===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440000 MHz
WDW
SSB 2
LB 0 Hz
GB 0





Current Data Parameters
NAME kl-200-HSQC-axial
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150904
Time 19.54
INSTRUM spect
PROBHD 5 mm PARBO BB/
PULPROG hsqcetgpsi2.3
TD 1024
SOLVENT CDCl3
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNS12 145.000000
CNS17 -0.5000000
D0 0.00000300 sec
D1 1.00000000 sec
D4 0.00172414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.00360000 sec
D24 0.00089000 sec
IN0 0.00003010 sec

===== CHANNEL f1 =====
SFO1 400.1458907 MHz
NUC1 13
P1 15.25 usec
P2 30.50 usec
P28 1000.00 usec
PLW1 12.00000000 W

===== CHANNEL f2 =====
SFO2 100.6233320 MHz
NUC2 13C
CPDPRG2 bl_p5m4sp_4ep.2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1900.00 usec
P63 1500.00 usec
PLW0 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SFOAL3 0.500
SPOFFS3 0 Hz
SPW3 SPNAM[7] Crp60decap.4
SFOAL7 0.500
SPOFFS7 0 Hz
SPW7 7.63940001 W
SPNAM[14] Crp32,1.5,20.2
SFOAL14 0.500
SPOFFS14 0 Hz
SPW14 3.25950003 W
SPNAM[18] Crp60_kfilc.2
SFOAL18 0.500
SPOFFS18 0 Hz
SPW18 1.83050001 W
SPNAM[31] Crp32,1.5,20.2
SFOAL31 0.500
SPOFFS31 0 Hz
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPNAM[3] SMSQ10.100
GPNAM[4] SMSQ10.100
GP21 80.00 %
GP22 20.10 %
GP23 11.00 %
GP24 5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 128
SFO1 100.6233 MHz
FIDRES 129.775742 Hz
SW 165.084 ppm
FMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440043 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162598 MHz
WDW
SSB 2
LB 0 Hz
GB 0

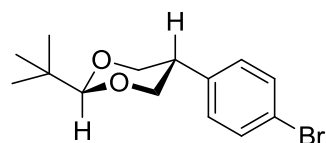


Current Data Parameters
NAME kl-200-H1-equatorial
EXPNO 1
PROCNO 1

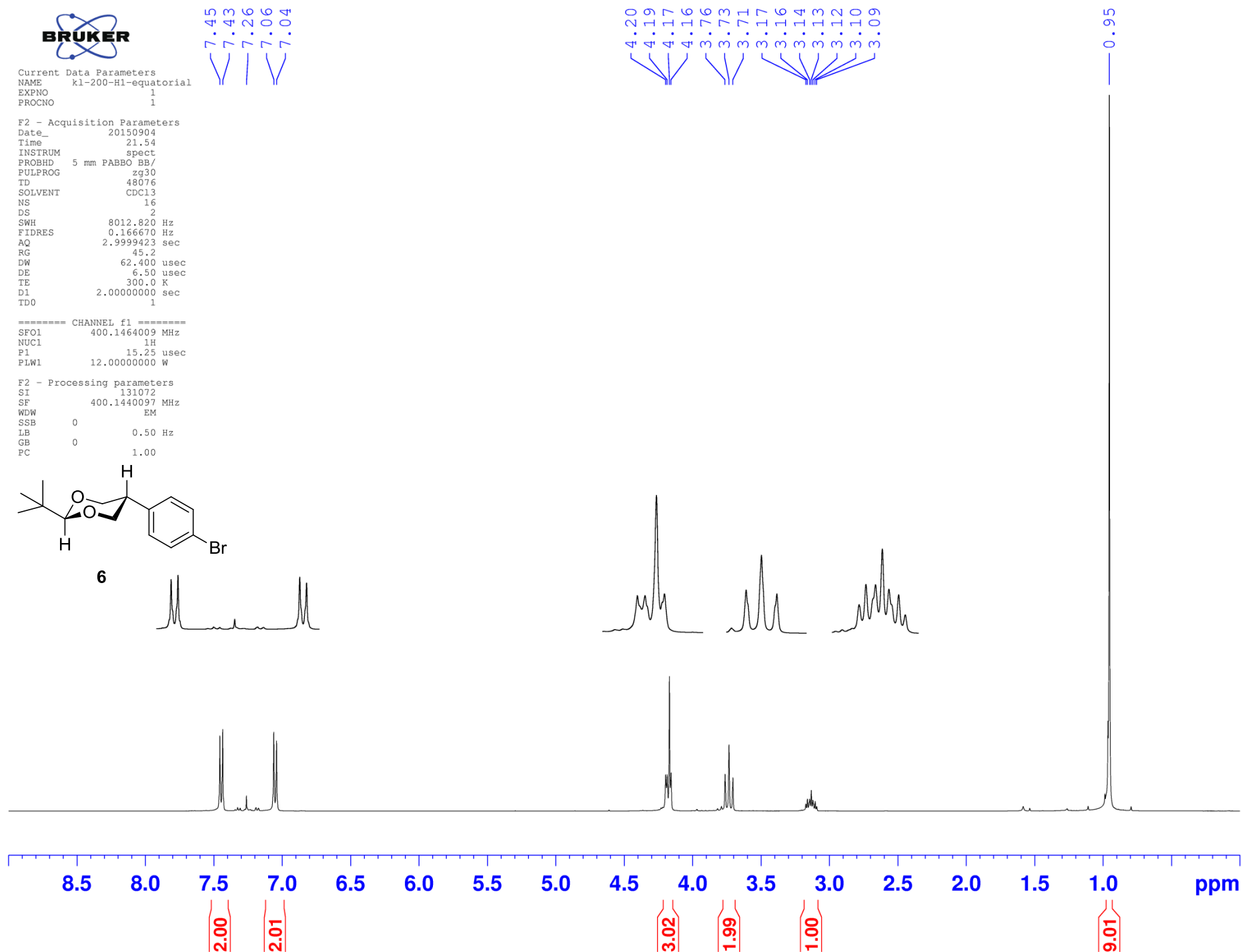
F2 - Acquisition Parameters
Date_ 20150904
Time 21.54
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 45.2
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440097 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00



6





Current Data Parameters
NAME kl-200-cl3-equatorial
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150904
Time 22.00
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 41
DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
AQ 0.8652204 sec
RG 203
DW 19.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

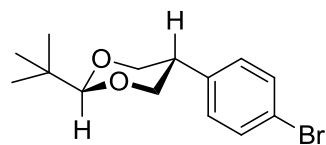
===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162692 MHz
WDW EM
SSB 0
LB 1.50 Hz
GB 0
PC 1.40

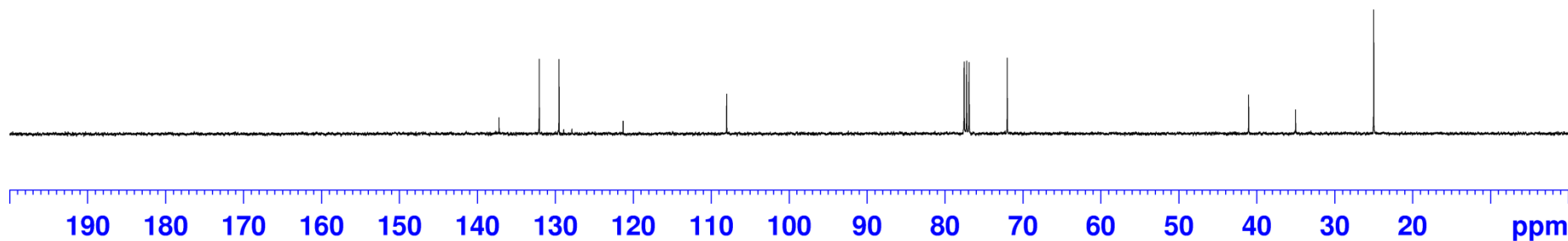
— 137.23
— 132.06
— 129.53
— 121.30
— 108.01

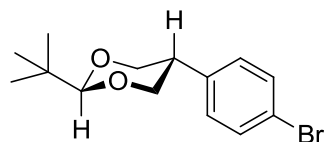
77.55
77.23
76.91
72.02

— 41.05
— 35.03
— 25.00

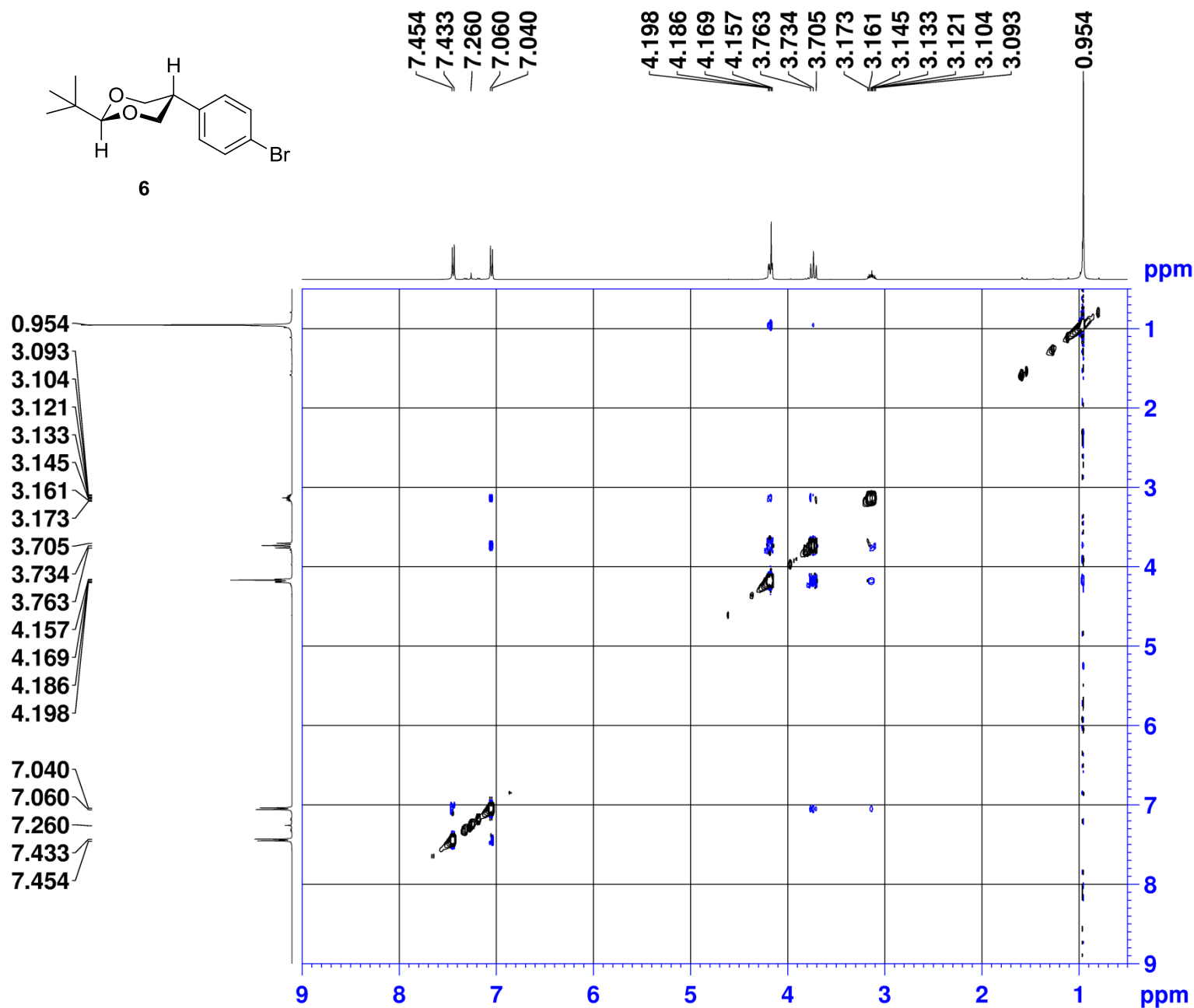


6





6



Current Data Parameters
NAME kl-200-HNOESY-equatorial
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150904
Time 22.25
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphpp
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 90.5
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

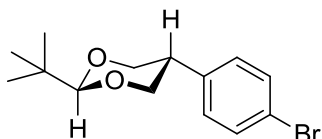
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440081 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440081 MHz
WDW
SSB 2
LB 0 Hz
GB 0



6

7.454
7.433
7.260
7.060
7.040



Current Data Parameters
NAME kl-200-HNOESY-equatorial
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150904
Time 22.25
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphpp
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 90.5
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

===== CHANNEL f1 =====
SF01 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

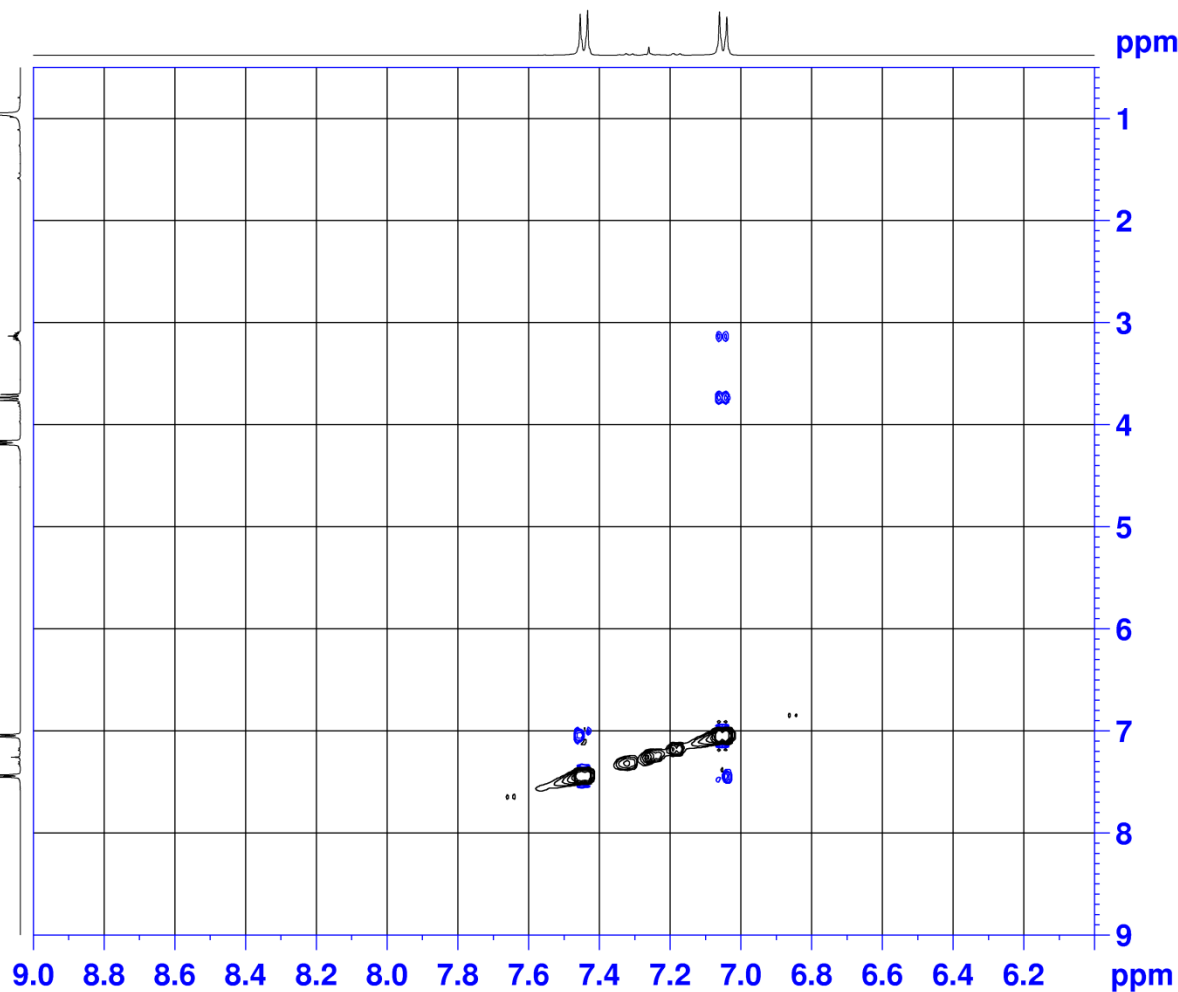
F1 - Acquisition parameters
TD 256
SF01 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

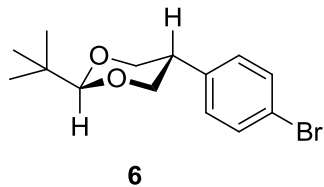
F2 - Processing parameters
SI 1024
SF 400.1440081 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440081 MHz
WDW
SSB 2
LB 0 Hz
GB 0

0.954
3.093
3.104
3.121
3.133
3.145
3.161
3.173
3.705
3.734
3.763
4.157
4.169
4.186
4.198

7.040
7.060
7.260
7.433
7.454

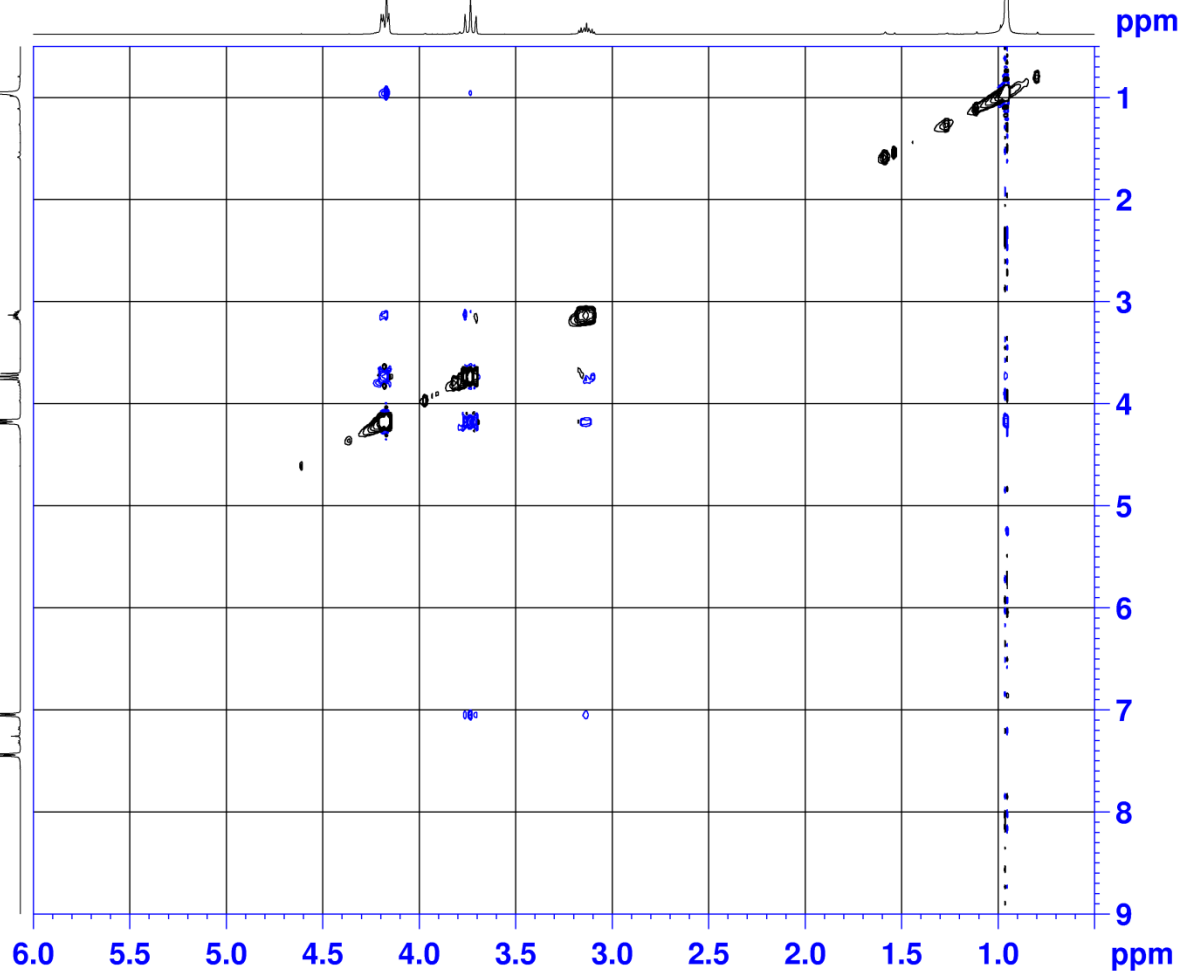




4.198
4.186
4.169
4.157
3.763
3.734
3.705
3.173
3.161
3.145
3.133
3.121
3.104
3.093

0.954

0.954
3.093
3.104
3.121
3.133
3.145
3.161
3.173
3.705
3.734
3.763
4.157
4.169
4.186
4.198
7.040
7.060
7.260
7.433
7.454



Current Data Parameters
NAME kl-200-HNOCY-equatorial
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150904
Time 22.25
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphpp
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 90.5
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

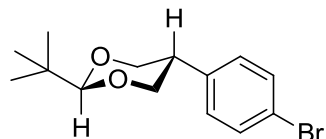
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440081 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440081 MHz
WDW
SSB 2
LB 0 Hz
GB 0



6

7.454
7.433
7.260
7.060
7.040

4.198
4.186
4.169
4.157
3.763
3.734
3.705
3.173
3.161
3.145
3.133
3.121
3.104
3.093

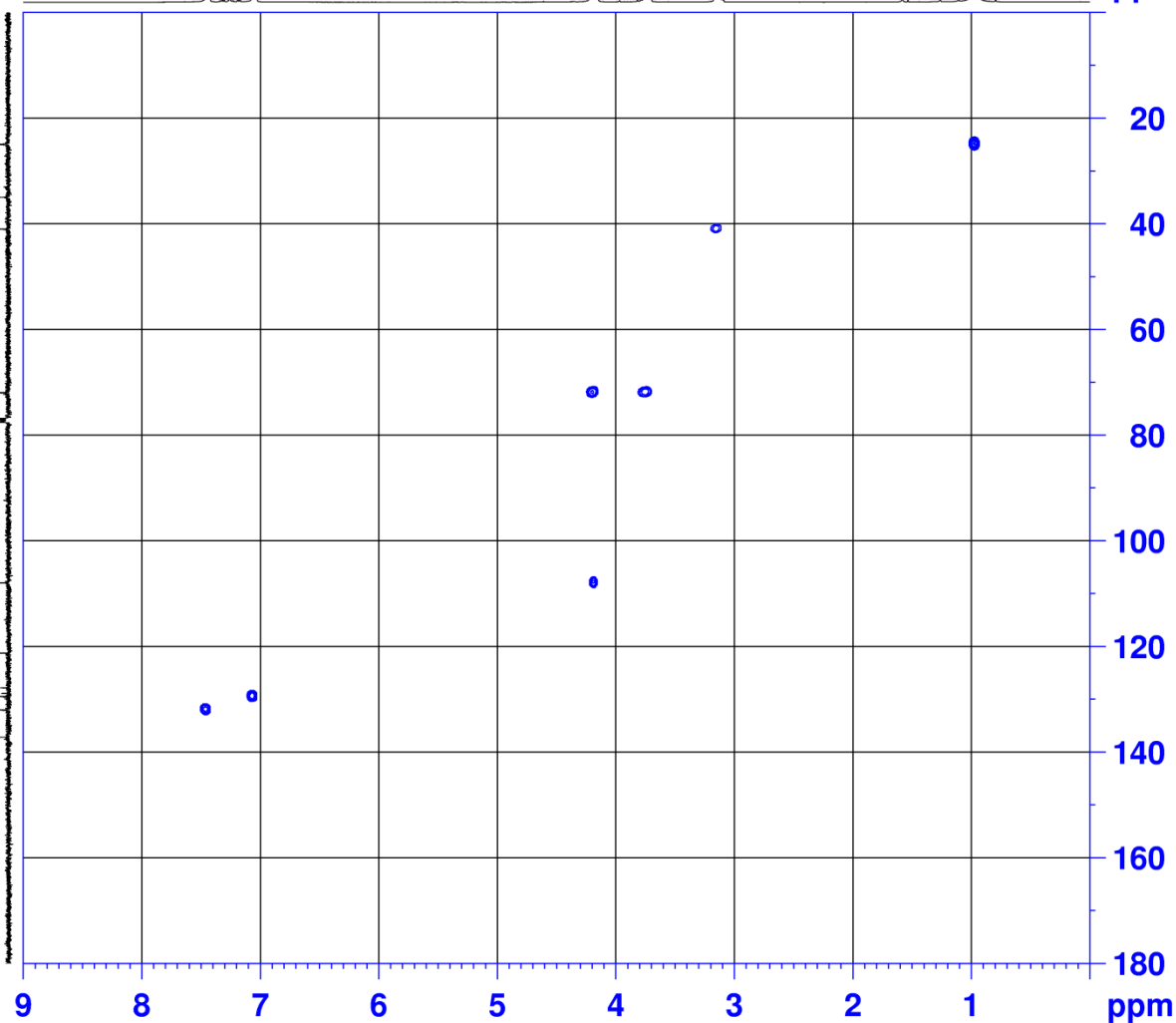
0.954

25.001
35.025
41.054

72.018
76.912
77.229
77.547

108.013

121.304
129.528
132.065
137.232



Current Data Parameters
NAME kl-200-HSQC-equatorial
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150904
Time 22.03
INSTRUM spect
PROBHD 5 mm PARBO BB/
PULPROG hsqcetgpsisp2.3
TD 1024
SOLVENT CDCl3
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNS17 145.000000
CNS17 -0.5000000
D0 0.00000300 sec
D1 1.00000000 sec
D4 0.00172414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.00360000 sec
D24 0.00089000 sec
IN0 0.00003010 sec

===== CHANNEL f1 =====
SFO1 400.1458907 MHz
NUC1 13
P1 15.25 usec
P2 30.50 usec
P28 1000.00 usec
PLW1 12.00000000 W

===== CHANNEL f2 =====
SFO2 100.6233320 MHz
NUC2 13C
CPDPRG2 2 bl_p5m4sp_4sp.2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1900.00 usec
P63 1500.00 usec
PLW0 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SFOAL3 0.500
SPOFFS3 0 Hz
SPW3 SPNAM[7] Crp60,0.5,20.1
SFOAL7 0.500
SPOFFS7 0 Hz
SPW7 7.63940001 W
SPNAM[14] Crp32,1.5,20.2
SFOAL14 0.500
SPOFFS14 0 Hz
SPW14 3.25950003 W
SPNAM[18] Crp60_kfilt.2
SFOAL18 0.500
SPOFFS18 0 Hz
SPW18 1.83050001 W
SPNAM[31] Crp32,1.5,20.2
SFOAL31 0.500
SPOFFS31 0 Hz
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPNAM[3] SMSQ10.100
GPNAM[4] SMSQ10.100
GP21 80.00 %
GP22 20.10 %
GP23 11.00 %
GP24 5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 128
SFO1 100.6233 MHz
FIDRES 129.775742 Hz
SW 165.084 ppm
FMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162890 MHz
WDW
SSB 2
LB 0 Hz
GB 0

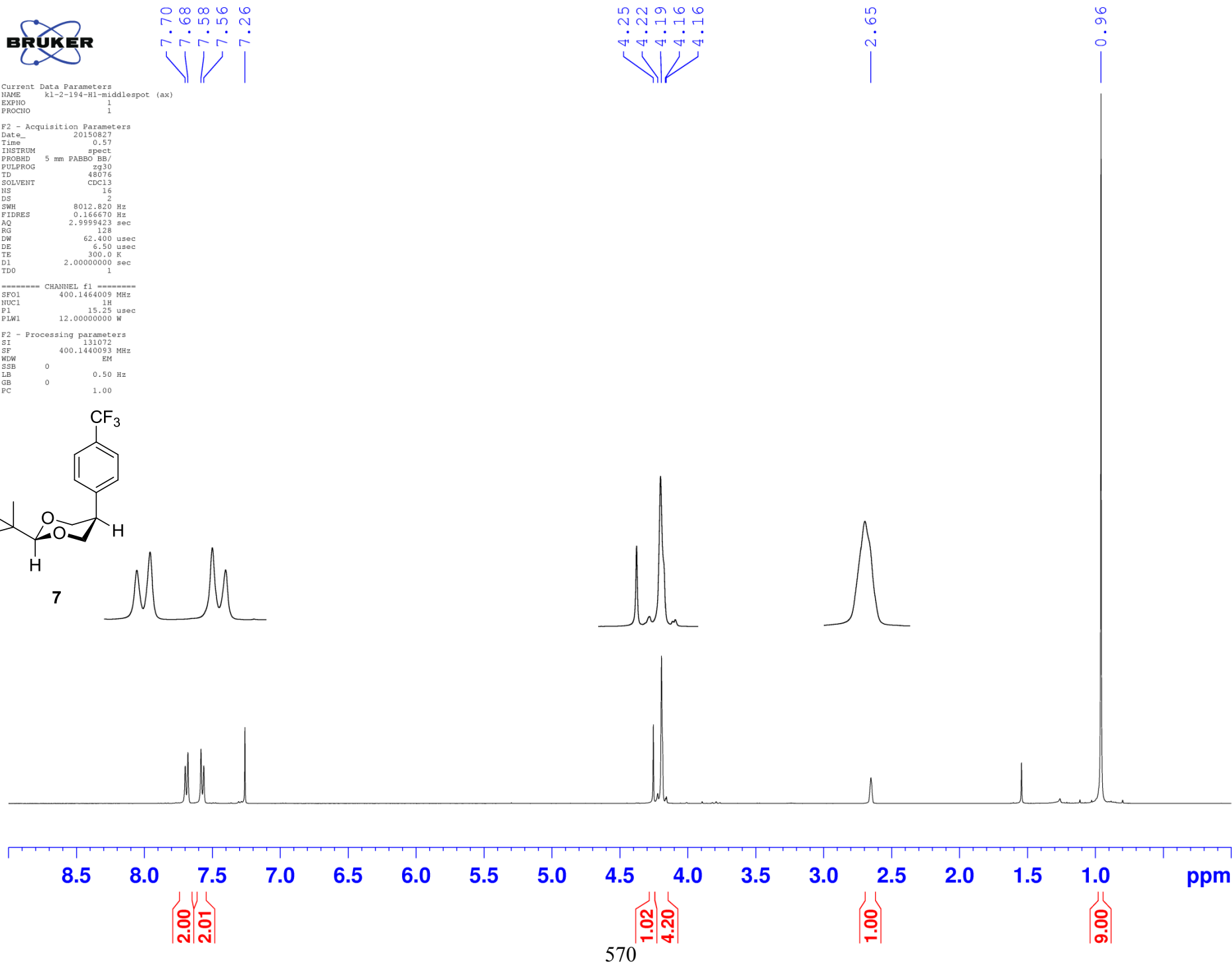
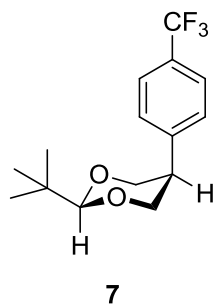


Current Data Parameters
NAME kl-2-194-H1-middlestop (ax)
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150827
Time 0.57
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDC13
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 128
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440093 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00





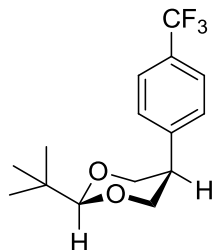
Current Data Parameters
NAME kl-2-194-cl3-middlespot (ax)
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150827
Time 3.36
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDC13
NS 1514
DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
AQ 0.8652204 sec
RG 203
DW 19.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

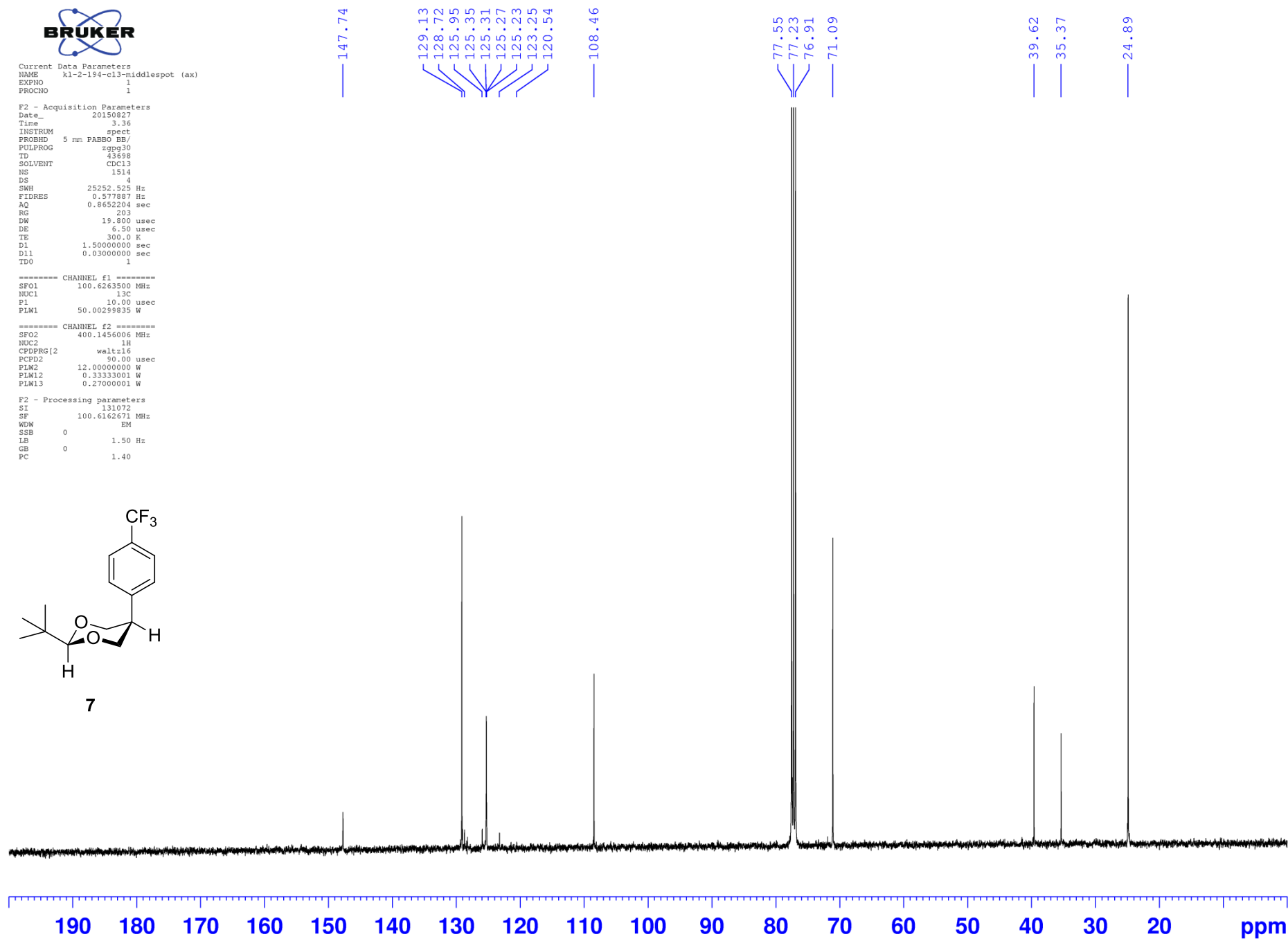
===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162671 MHz
WDW EM
SSB 0
LB 1.50 Hz
GB 0
PC 1.40



7





Current Data Parameters
NAME kl-2-194-f19-middlespot (ax)
EXPNO 1
PROCNO 1

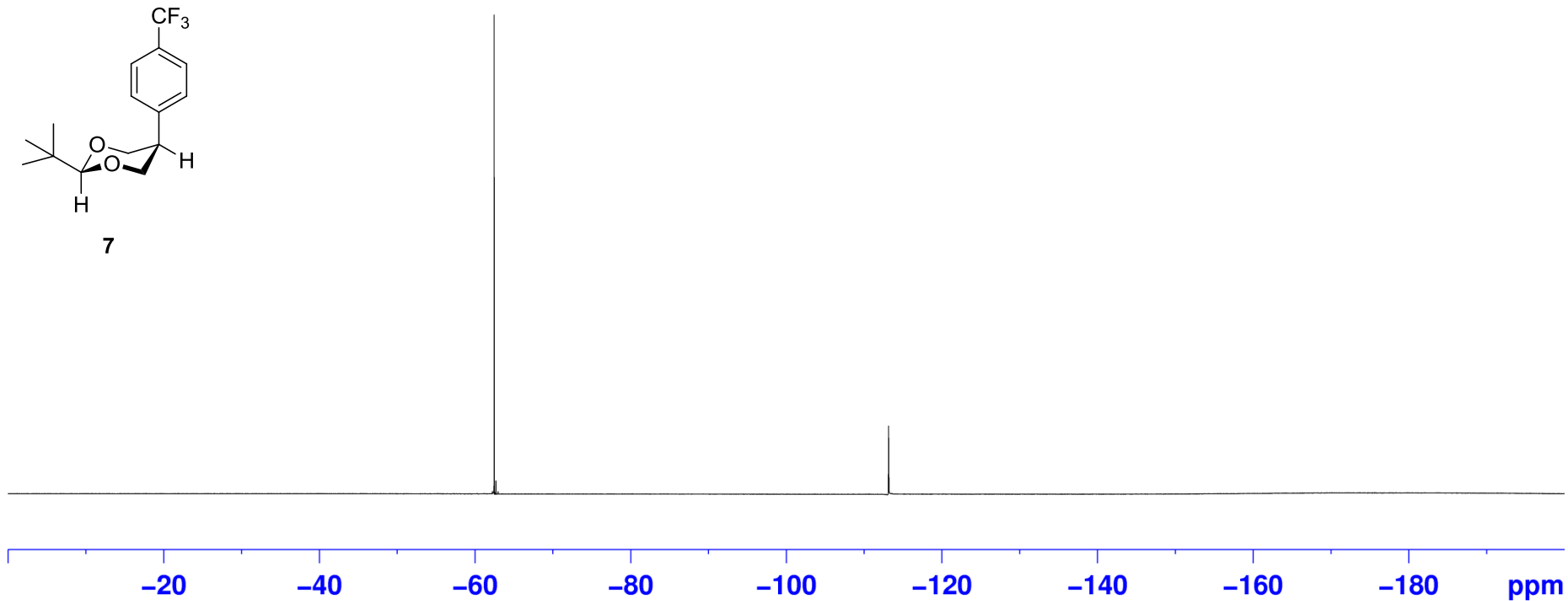
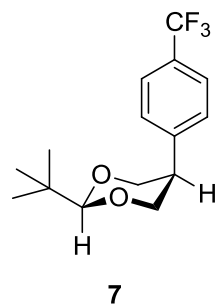
F2 - Acquisition Parameters
Date_ 20150827
Time 3.43
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 131072
SOLVENT CDC13
NS 8
DS 4
SWH 89285.711 Hz
FIDRES 0.681196 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 1.00000000 sec
TD0 1

===== CHANNEL f1 =====
SF01 376.4738882 MHz
NUC1 19F
P1 14.00 usec
PLW1 18.00000000 W

F2 - Processing parameters
SI 65536
SF 376.5115641 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

— — — 62.47

113.11
113.13
113.13
113.14
113.15
113.16
113.17
113.17
113.19





Current Data Parameters
NAME kl-2-194-HNOESY-middlespot (ax)
EXPNO 1
PROCNO 1

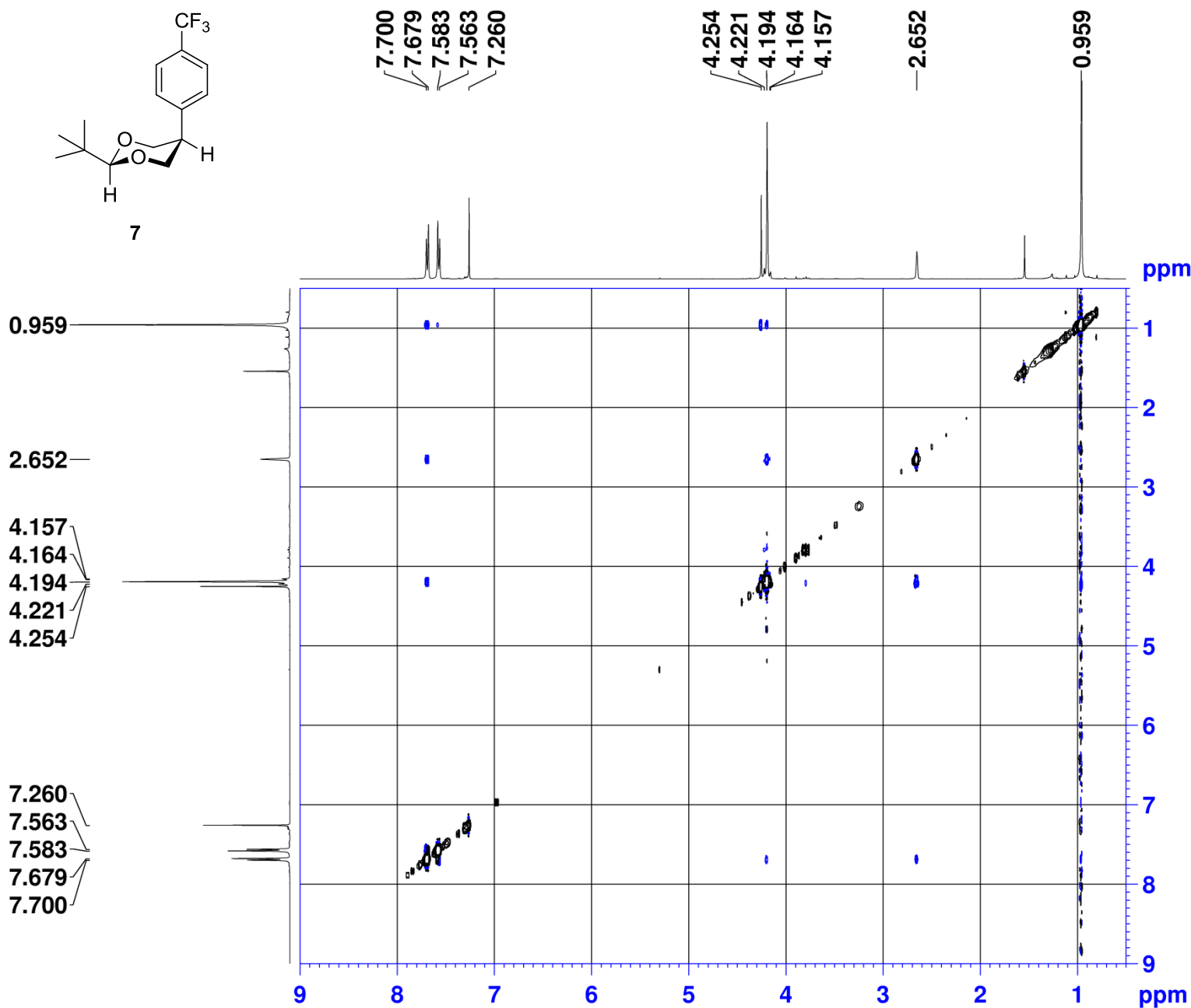
F2 - Acquisition Parameters
Date_ 20150827
Time 1.32
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphpp
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

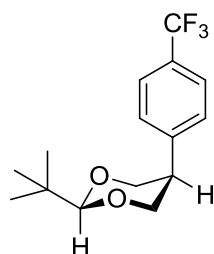
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W
===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GP21 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440082 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

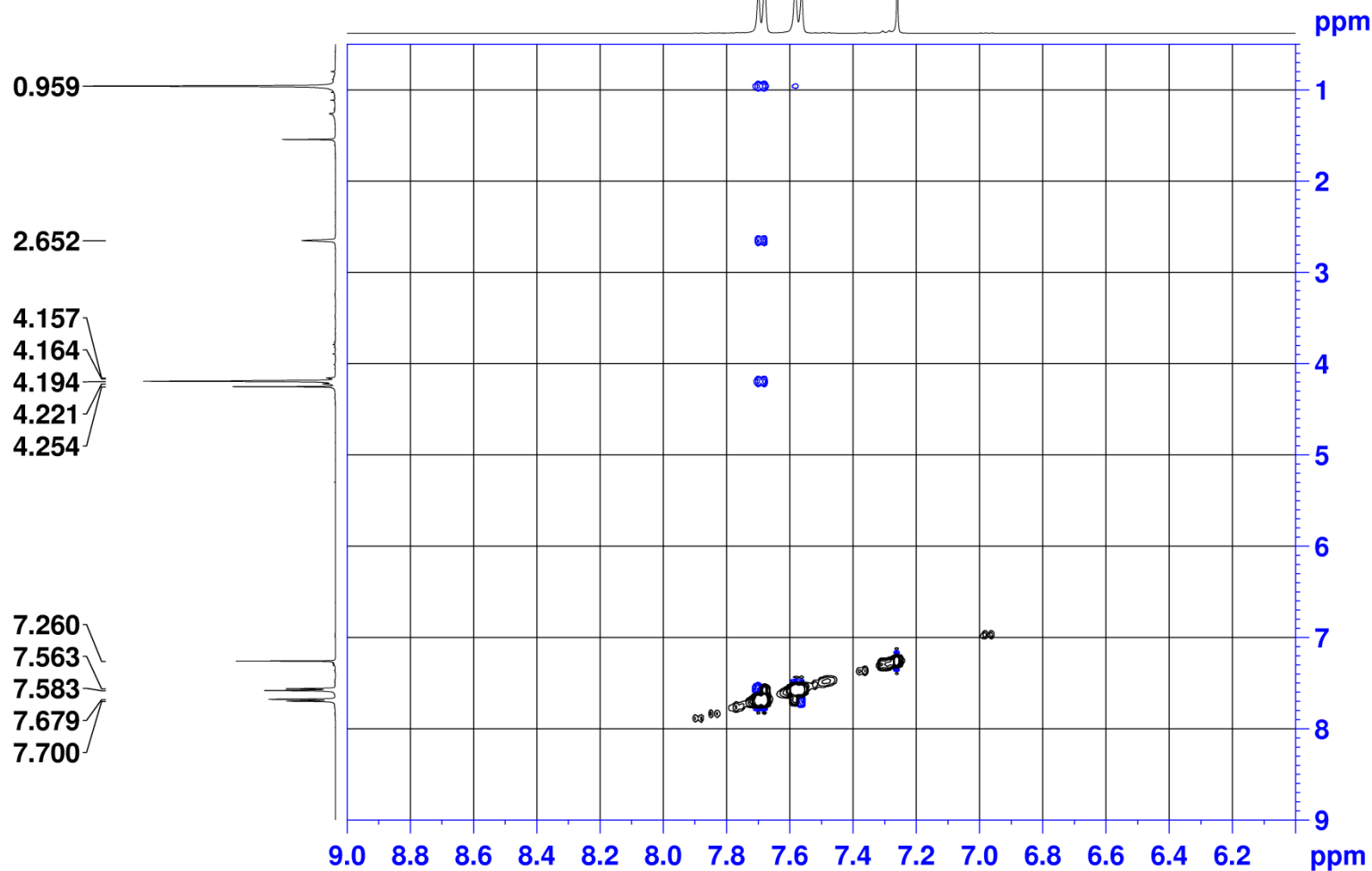
F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440082 MHz
WDW
SSB 2
LB 0 Hz
GB 0





7

7.700
7.679
7.583
7.563
7.260



Current Data Parameters
NAME kl-2-194-HNOCESY-middlespot (ax)
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150827
Time 1.32
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphph
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

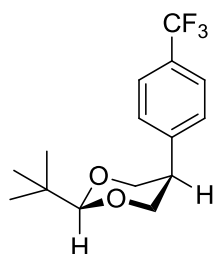
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GP21 40.00 %
P16 1000.00 usec

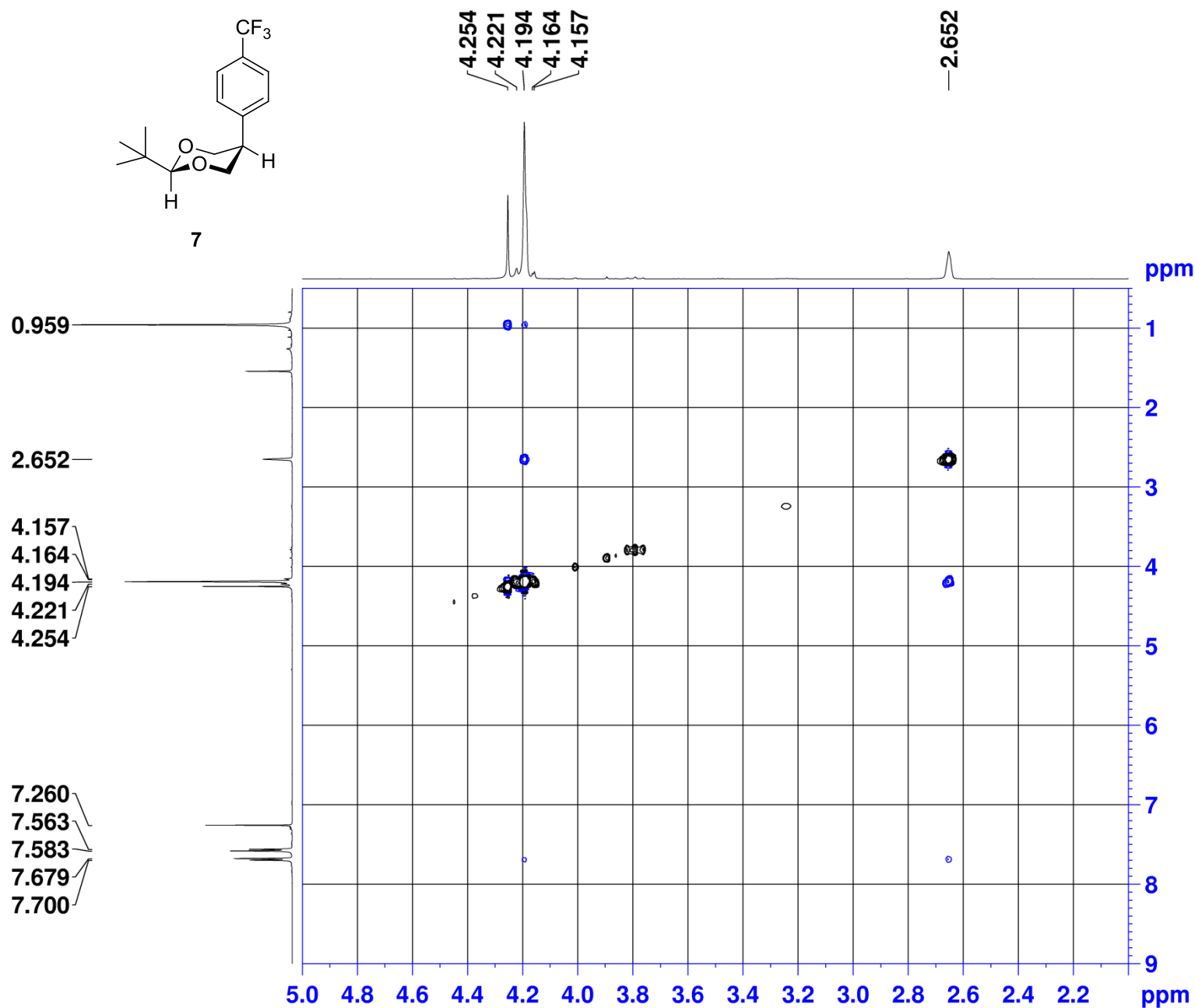
F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440082 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440082 MHz
WDW
SSB 2
LB 0 Hz
GB 0



7



Current Data Parameters
NAME kl-2-194-HNOESY-middlespot (ax)
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150827
Time 1.32
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphph
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00020000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

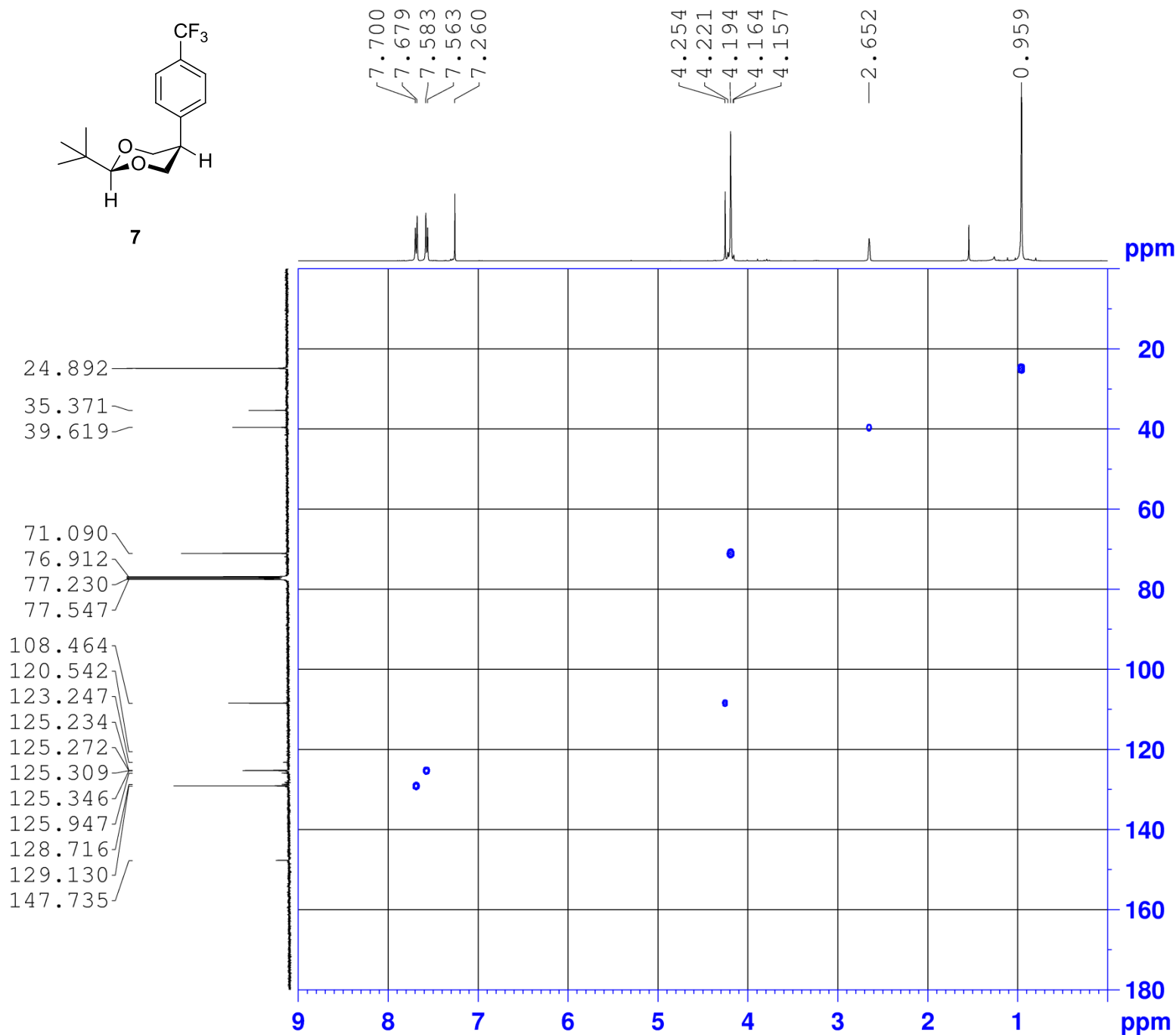
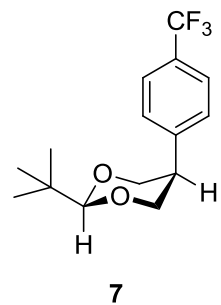
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GP21 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440082 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440082 MHz
WDW
SSB 2
LB 0 Hz
GB 0



Current Data Parameters
 NAME kl-2-194-HSQC-middlespot (ax)
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20150821
 Time 1.01
 INSTRUM spect
 PROBHD 5 mm PARBO BB/
 PULPROG hsqcetgpsisp2.3
 TD 1024
 SOLVENT CDCl3
 NS 4
 DS 16
 SWH 6410.256 Hz
 FIDRES 6.260016 Hz
 AQ 0.0798720 sec
 RG 203
 DW 78.000 usec
 DE 6.50 usec
 TE 300.0 K
 CNST2 145.000000
 CNST17 -0.500000
 D0 0.00000300 sec
 D1 1.00000000 sec
 D4 0.00172414 sec
 D11 0.03000000 sec
 D16 0.00020000 sec
 D21 0.00360000 sec
 D24 0.00089000 sec
 IN0 0.00003010 sec

===== CHANNEL f1 =====
 SFO1 400.145807 MHz
 NUC1 13
 P1 15.25 usec
 P2 30.50 usec
 P28 1000.00 usec
 PLW1 12.00000000 W

===== CHANNEL f2 =====
 SFO2 100.623320 MHz
 NUC2 13C
 CPDPRG2 bl_p5m4sp_4sp.2
 P3 10.00 usec
 P14 500.00 usec
 P24 2000.00 usec
 P31 1900.00 usec
 P63 1500.00 usec
 PLW0 0 W
 PLW2 50.00000000 W
 PLW12 0.78125000 W
 SPNAM[3] Crp60,0.5,20.1
 SPOAL3 0.500
 SPOFFS3 0 Hz
 SPW3 7.63940001 W
 SPNAM[7] Crp60decp.4
 SPOAL7 0.500
 SPOFFS7 0 Hz
 SPW7 7.63940001 W
 SPNAM[14] Crp32,1.5,20.2
 SPOAL14 0.500
 SPOFFS14 0 Hz
 SPW14 3.25950003 W
 SPNAM[18] Crp60_kfilt.2
 SPOAL18 0.500
 SPOFFS18 0 Hz
 SPW18 1.83050001 W
 SPNAM[31] Crp32,1.5,20.2
 SPOAL31 0.500
 SPOFFS31 0 Hz
 SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
 GPNAM[1] SMSQ10.100
 GPNAM[2] SMSQ10.100
 GPNAM[3] SMSQ10.100
 GPNAM[4] SMSQ10.100
 GP21 80.00 %
 GP22 20.10 %
 GP23 11.00 %
 GP24 5.00 %
 P16 1000.00 usec
 P19 600.00 usec

F1 - Acquisition parameters
 TD 128
 SFO1 100.6233 MHz
 FIDRES 129.775742 Hz
 SW 165.084 ppm
 FMODE Echo-Antiecho

F2 - Processing parameters
 SI 1024
 SF 400.1440070 MHz
 WDW QSI
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.40

F1 - Processing parameters
 SI 1024
 MC2 echo-antiecho
 SF 100.6162585 MHz
 WDW States
 SSB 2
 LB 0 Hz
 GB 0

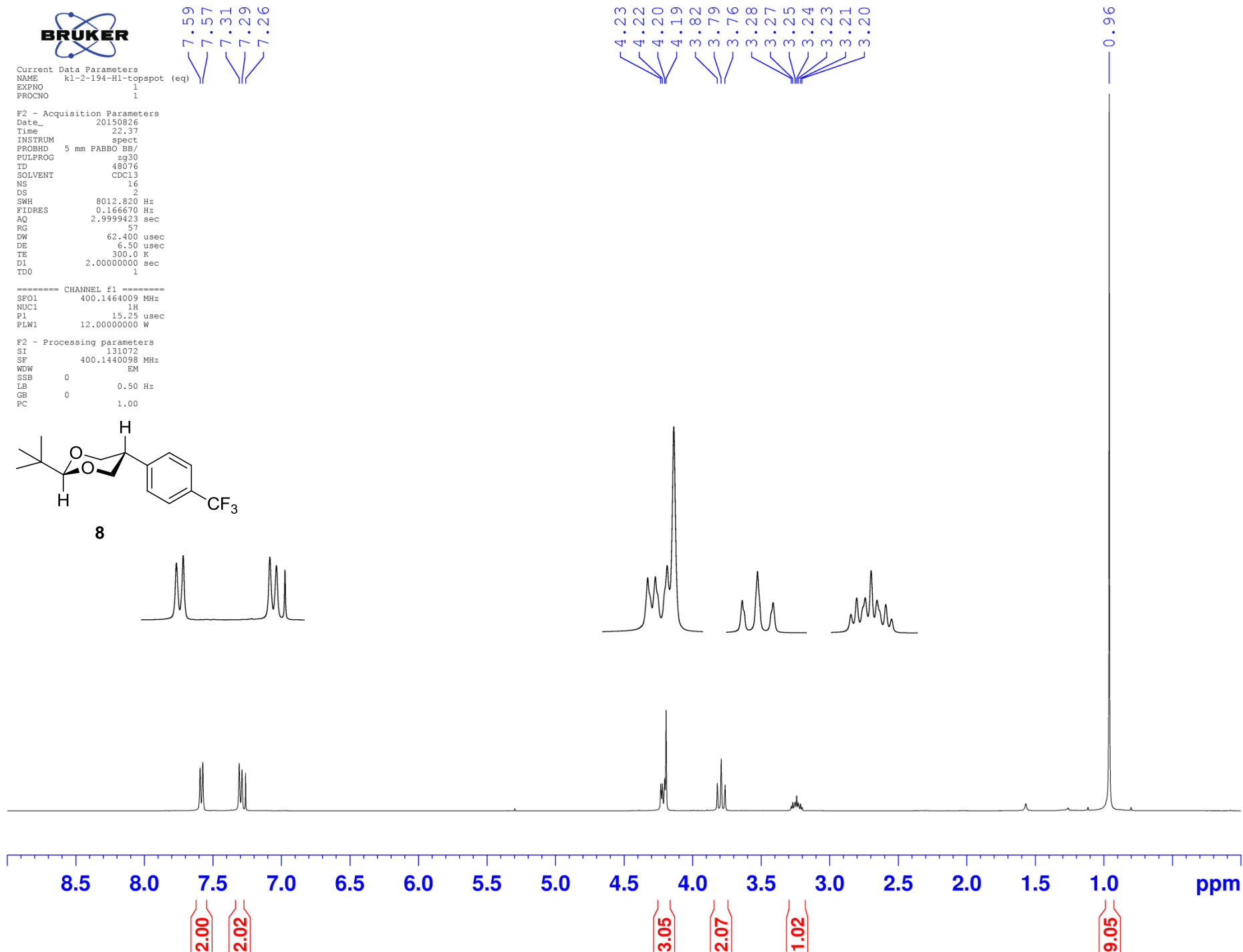
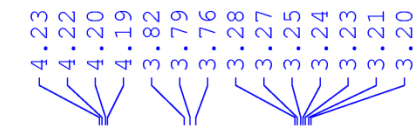
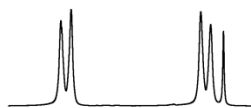
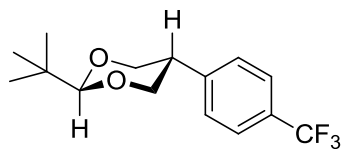


Current Data Parameters
NAME kl-2-194-H1-topspot (eq)
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150826
Time 22.37
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 57
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SF01 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440098 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00



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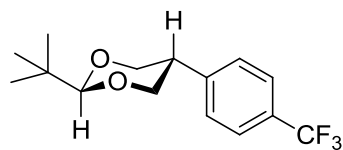
Current Data Parameters
NAME kl-2-194-cl3-topsot (eq)
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150826
Time 23.34
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 1316
DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
AQ 0.8652204 sec
RG 203
DW 19.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

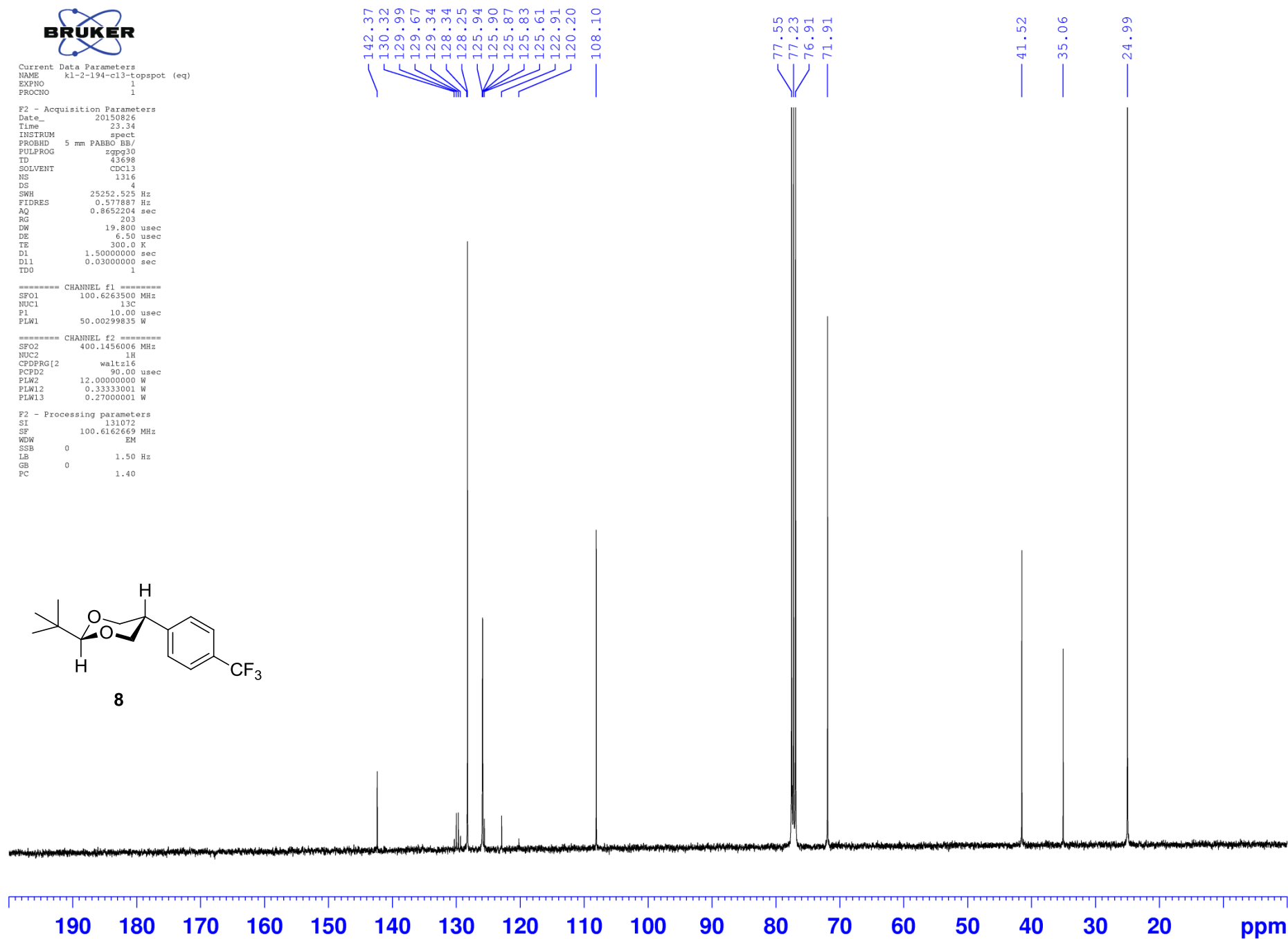
===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162669 MHz
WDW EM
SSB 0
LB 1.50 Hz
GB 0
PC 1.40



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Current Data Parameters
NAME kl-2-194-F19-topspot (eq)
EXPNO 1
PROCNO 1

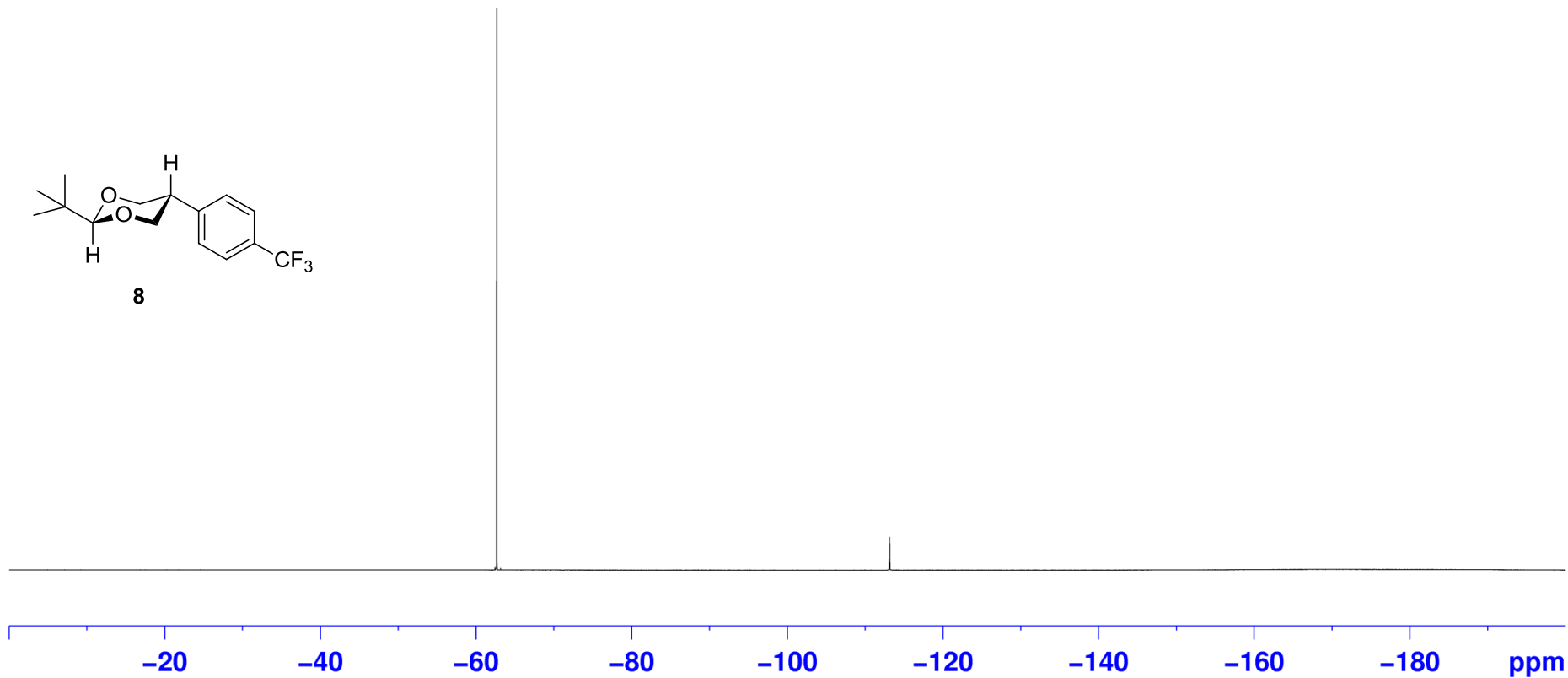
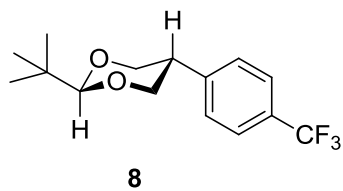
F2 - Acquisition Parameters
Date_ 20150827
Time 0.51
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 131072
SOLVENT CDCl3
NS 8
DS 4
SWH 89285.711 Hz
FIDRES 0.681196 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 1.00000000 sec
TD0 1

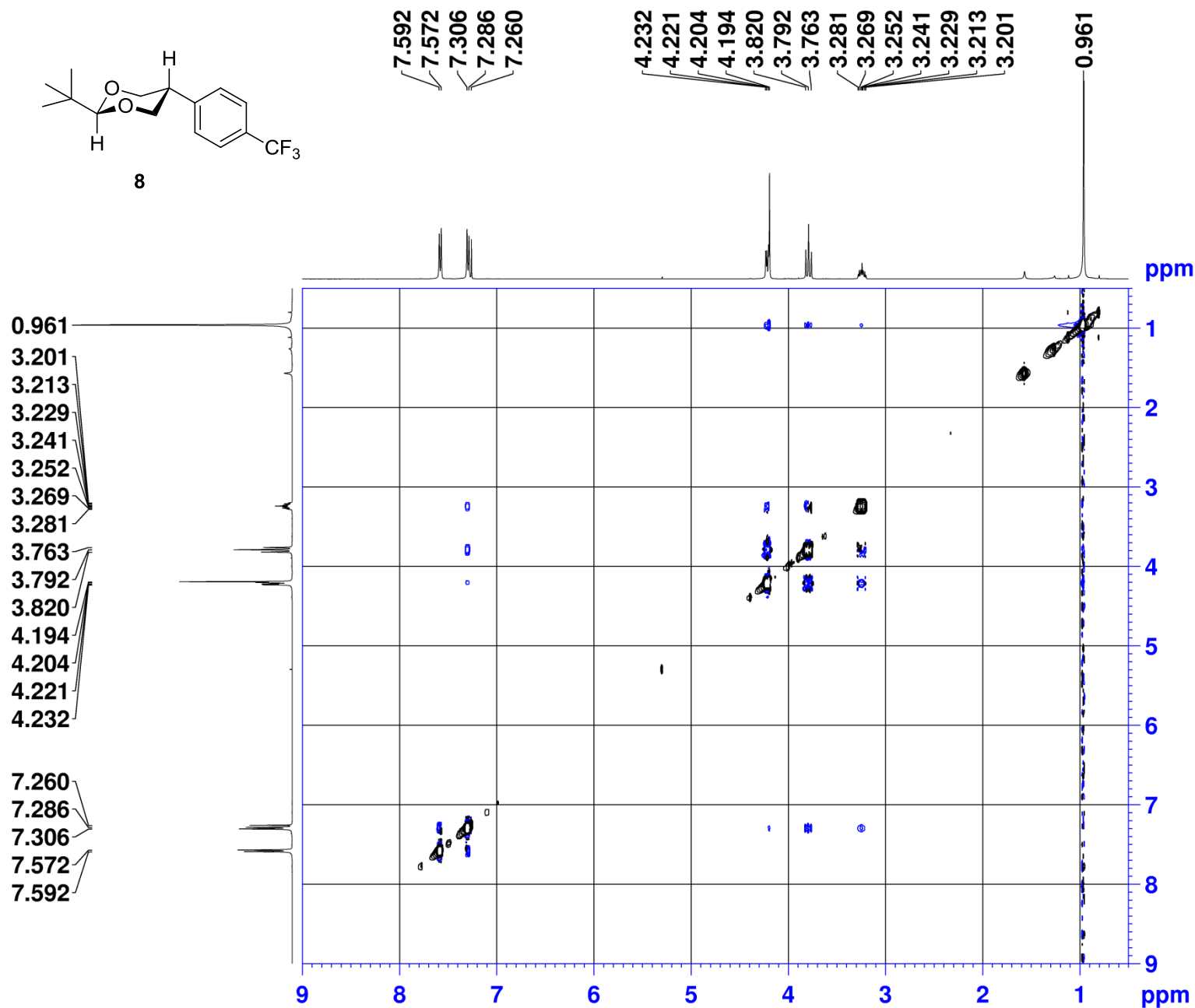
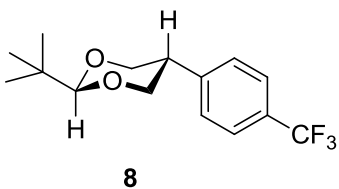
===== CHANNEL f1 =====
SFO1 376.4738882 MHz
NUC1 19F
P1 14.00 usec
PLW1 18.00000000 W

F2 - Processing parameters
SI 65536
SF 376.5115696 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

— -62.70

-113.12
-113.13
-113.14
-113.14
-113.16
-113.16
-113.17
-113.18
-113.19
-113.23





Current Data Parameters
 NAME kl-2-194-HNOESY-topspot (eq)
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20150826
 Time 23.37
 INSTRUM spect
 PROBHD 5 mm PABBO BB/
 PULPROG noesygpph
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 32
 SWH 4084.967 Hz
 FIDRES 1.994613 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 D0 0.00010330 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec

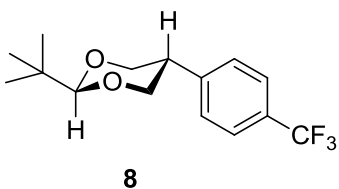
===== CHANNEL f1 =====
 SF01 400.1458419 MHz
 NUC1 1H
 P1 15.00 usec
 P2 30.00 usec
 P17 2500.00 usec
 PLW1 12.00000000 W
 PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SF01 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FnmODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440081 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440081 MHz
 WDW
 SSB 2
 LB 0 Hz
 GB 0



7.592
7.572

7.306
7.286
7.260



Current Data Parameters
NAME kl-2-194-HNOESY-topspot (eq)
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150826
Time 23.37
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphph
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

===== CHANNEL f1 =====
SF01 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

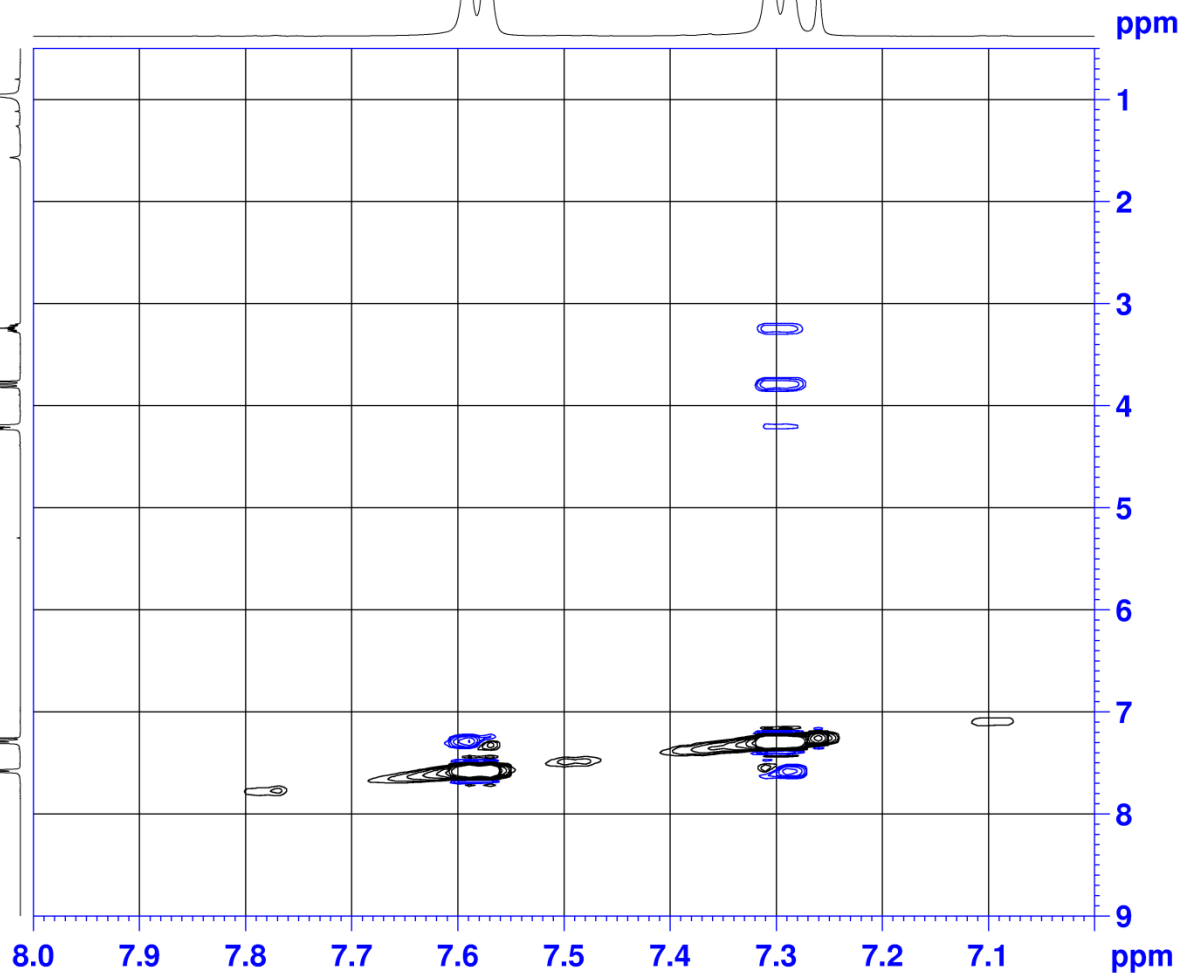
F1 - Acquisition parameters
TD 256
SF01 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

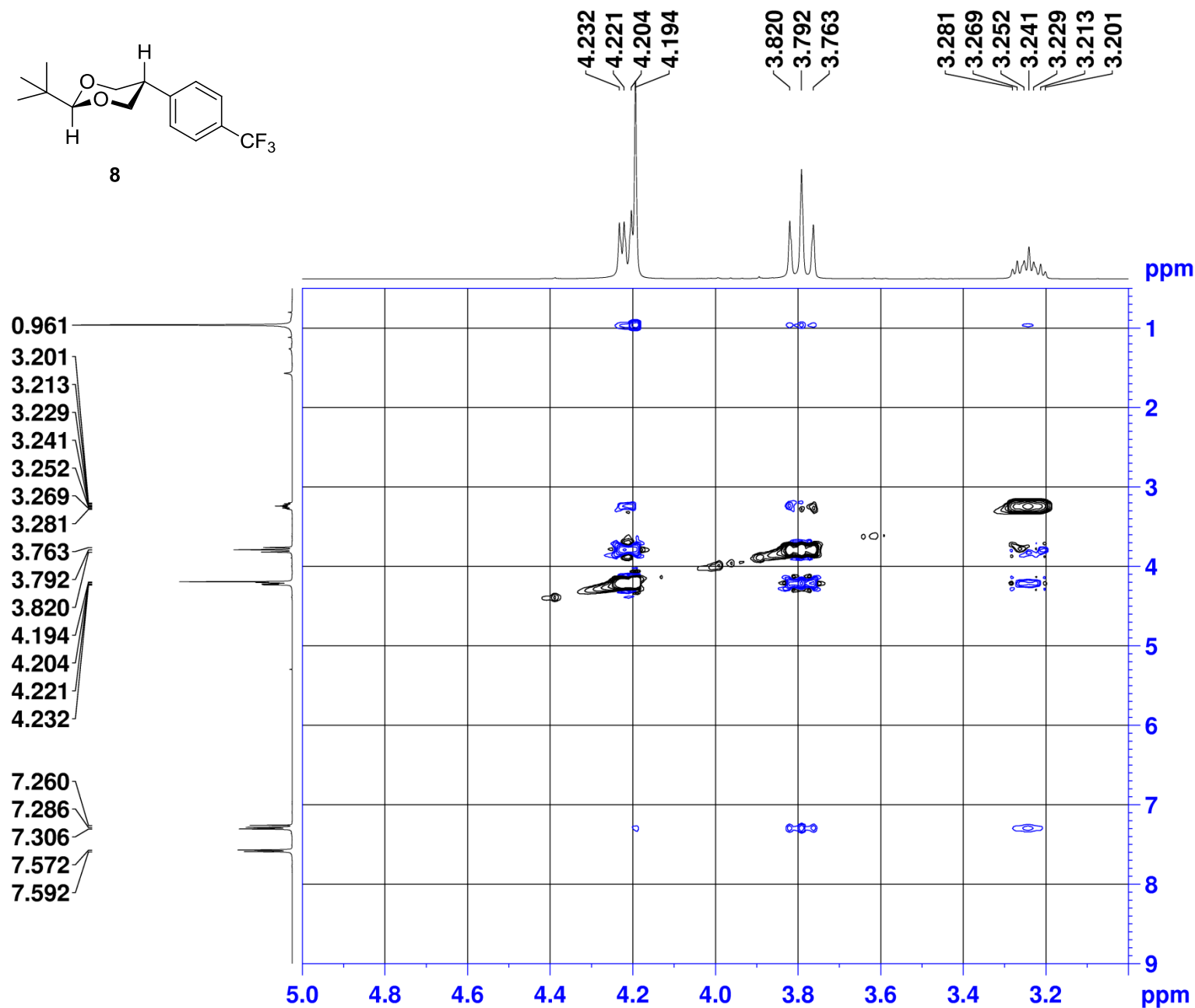
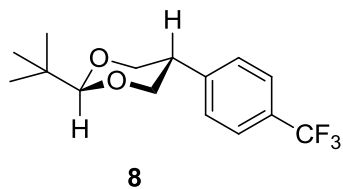
F2 - Processing parameters
SI 1024
SF 400.1440081 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440081 MHz
WDW
SSB 2
LB 0 Hz
GB 0

0.961
3.201
3.213
3.229
3.241
3.252
3.269
3.281
3.763
3.792
3.820
4.194
4.204
4.221
4.232

7.260
7.286
7.306
7.572
7.592





Current Data Parameters
NAME kl-2-194-HNOESY-topspot (eq)
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150826
Time 23.37
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpph
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

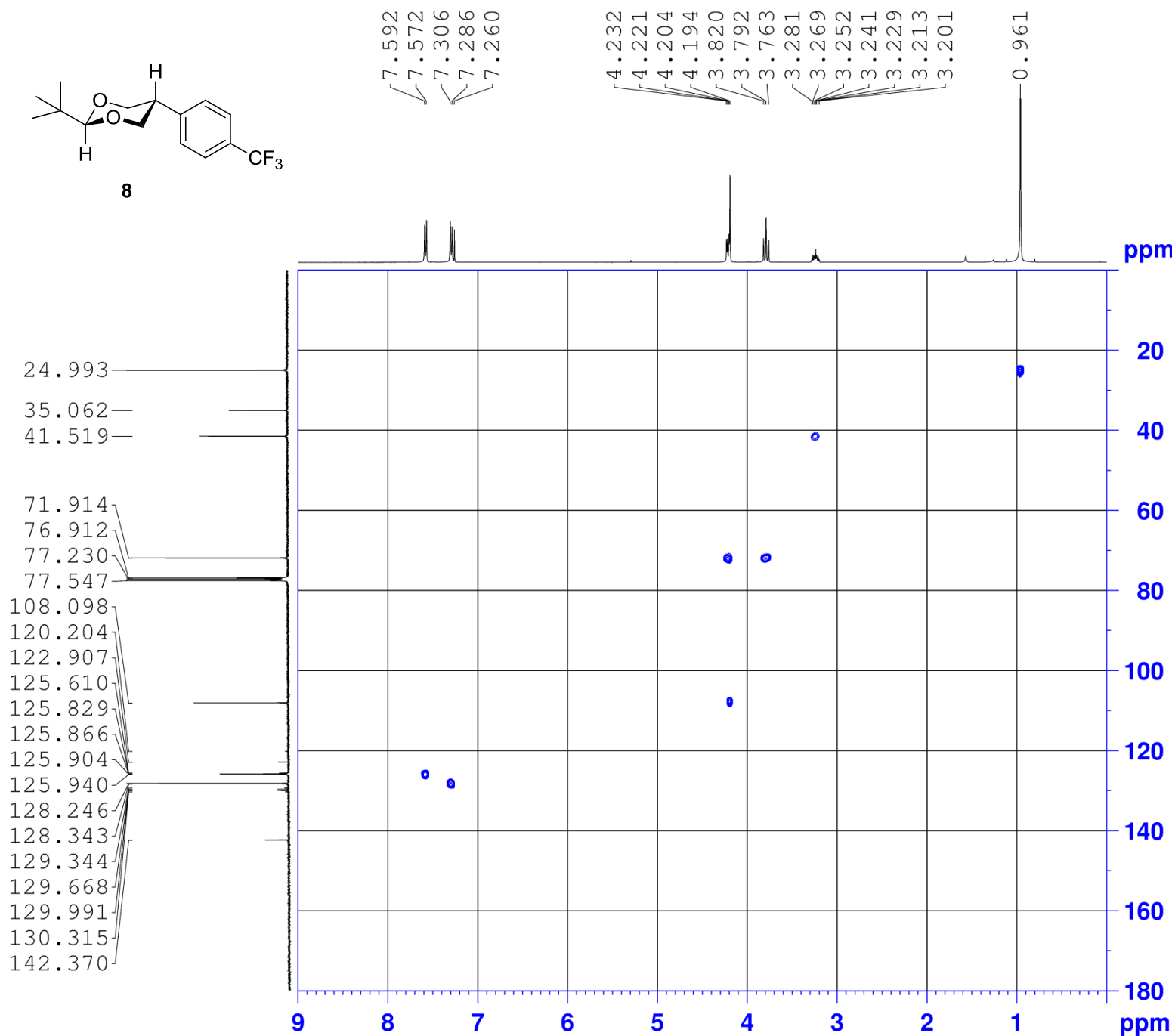
===== CHANNEL f1 =====
SF01 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SF01 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440081 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440081 MHz
WDW
SSB 2
LB 0 Hz
GB 0



Current Data Parameters
NAME kl-2-194-Hsqq-topspot (eq)
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150821
Time 0.32
INSTRUM spect
PROBHD 5 mm PARBO BB/
PULPROG hsqcetgpsisp2.3
TD 1024
SOLVENT CDCl₃
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNS12 145.000000
CNS17 -0.500000
D0 0.00000300 sec
D1 1.00000000 sec
D4 0.00172414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.00360000 sec
D24 0.00089000 sec
IN0 0.00003010 sec

===== CHANNEL f1 =====
SFO1 400.1458807 MHz
NUC1 13
P1 15.25 usec
P2 30.50 usec
P28 1000.00 usec
PLW1 12.00000000 W

===== CHANNEL f2 =====
SFO2 100.6233320 MHz
NUC2 13C
CPDPRG2 bl_p5m4sp_4sp.2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1900.00 usec
P63 1500.00 usec
PLW0 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SFOAL3 0.500
SPOFFS3 0 Hz
SPW3 SPNAM[7] 7.63940001 W
SFOAL7 Crp60deep.4
SPOAL7 0.500
SPOFFS7 0 Hz
SPW7 7.63940001 W
SPNAM[14] Crp32,1.5,20.2
SFOAL14 0.500
SPOFFS14 0 Hz
SPW14 3.25950003 W
SPNAM[18] Crp60_kfilt.2
SFOAL18 0.500
SPOFFS18 0 Hz
SPW18 1.83050001 W
SPNAM[31] Crp32,1.5,20.2
SFOAL31 0.500
SPOFFS31 0 Hz
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPNAM[3] SMSQ10.100
GPNAM[4] SMSQ10.100
GP21 80.00 %
GP22 20.10 %
GP23 11.00 %
GP24 5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 47
SFO1 100.6233 MHz
FIDRES 352.433824 Hz
SW 165.084 ppm
FMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440070 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162616 MHz
WDW
SSB 2
LB 0 Hz
GB 0

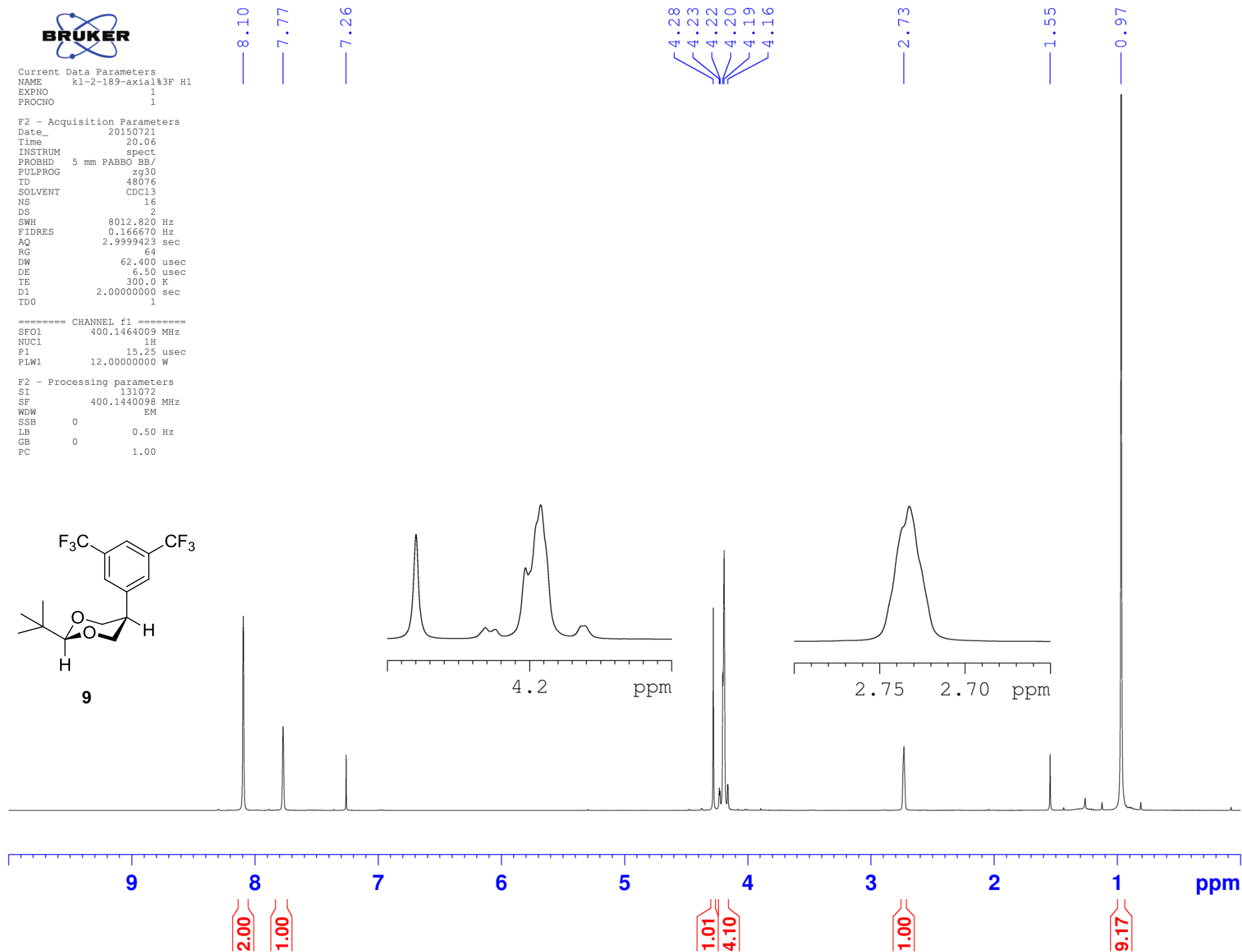
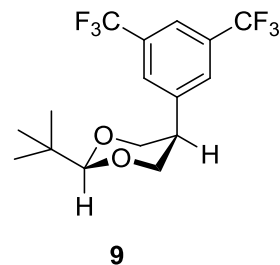


Current Data Parameters
NAME k1-2-189-axial%3F H1
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150721
Time 20.06
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDC13
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 64
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440098 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00





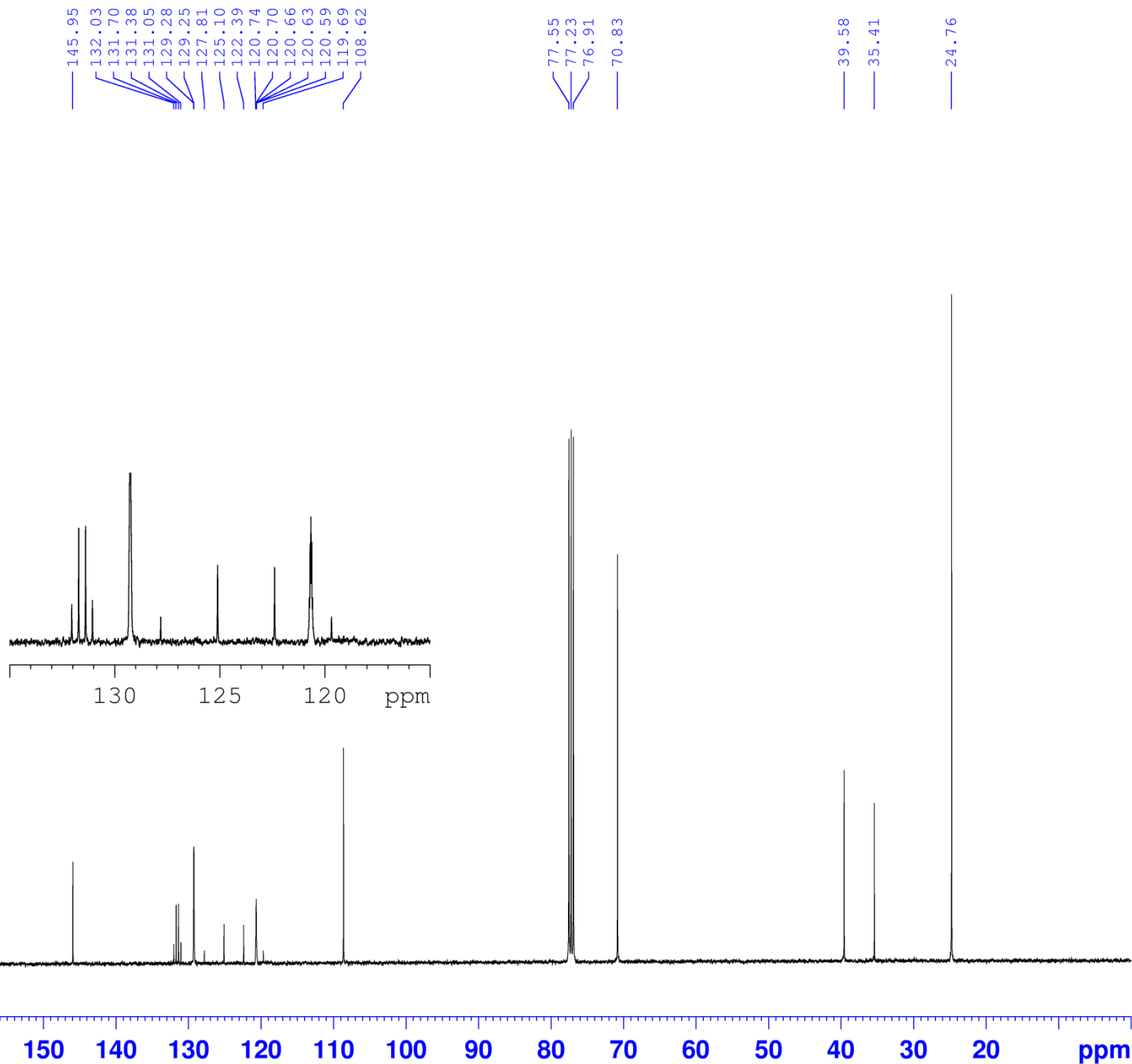
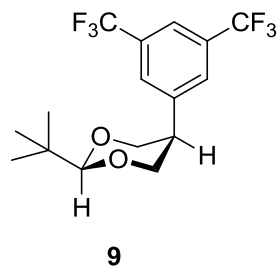
Current Data Parameters
NAME kl-2-189-axial¹³F c13
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150721
Time 21.05
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl₃
NS 1340
DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
AQ 0.8652204 sec
RG 203
DW 19.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 ¹³C
P1 10.00 usec
PLW1 50.00299835 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 ¹H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162660 MHz
WDW EM
SSB 0
LB 1.50 Hz
GB 0
PC 1.40





Current Data Parameters
NAME kl-2-189-axial-F19
EXPNO 1
PROCNO 1

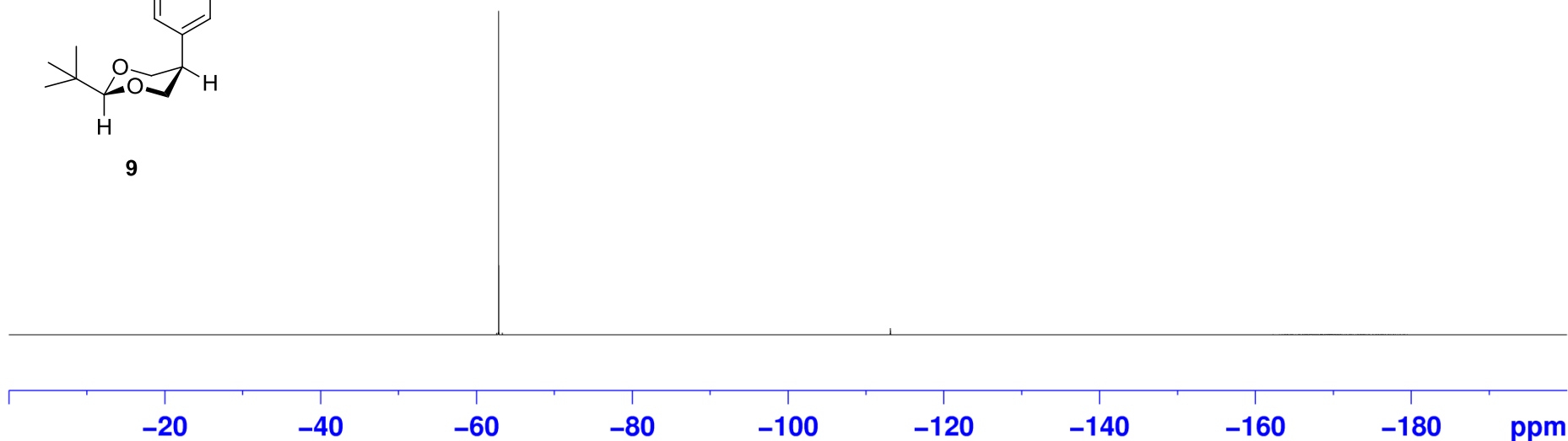
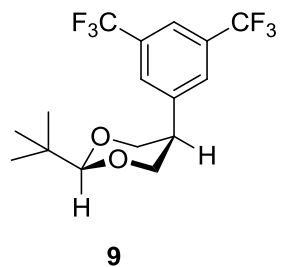
F2 - Acquisition Parameters
Date_ 20150722
Time 3.44
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgfgqn
TD 131072
SOLVENT CDCl3
NS 8
DS 4
SWH 89285.711 Hz
FIDRES 0.681196 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 1.0000000 sec
TD0 1

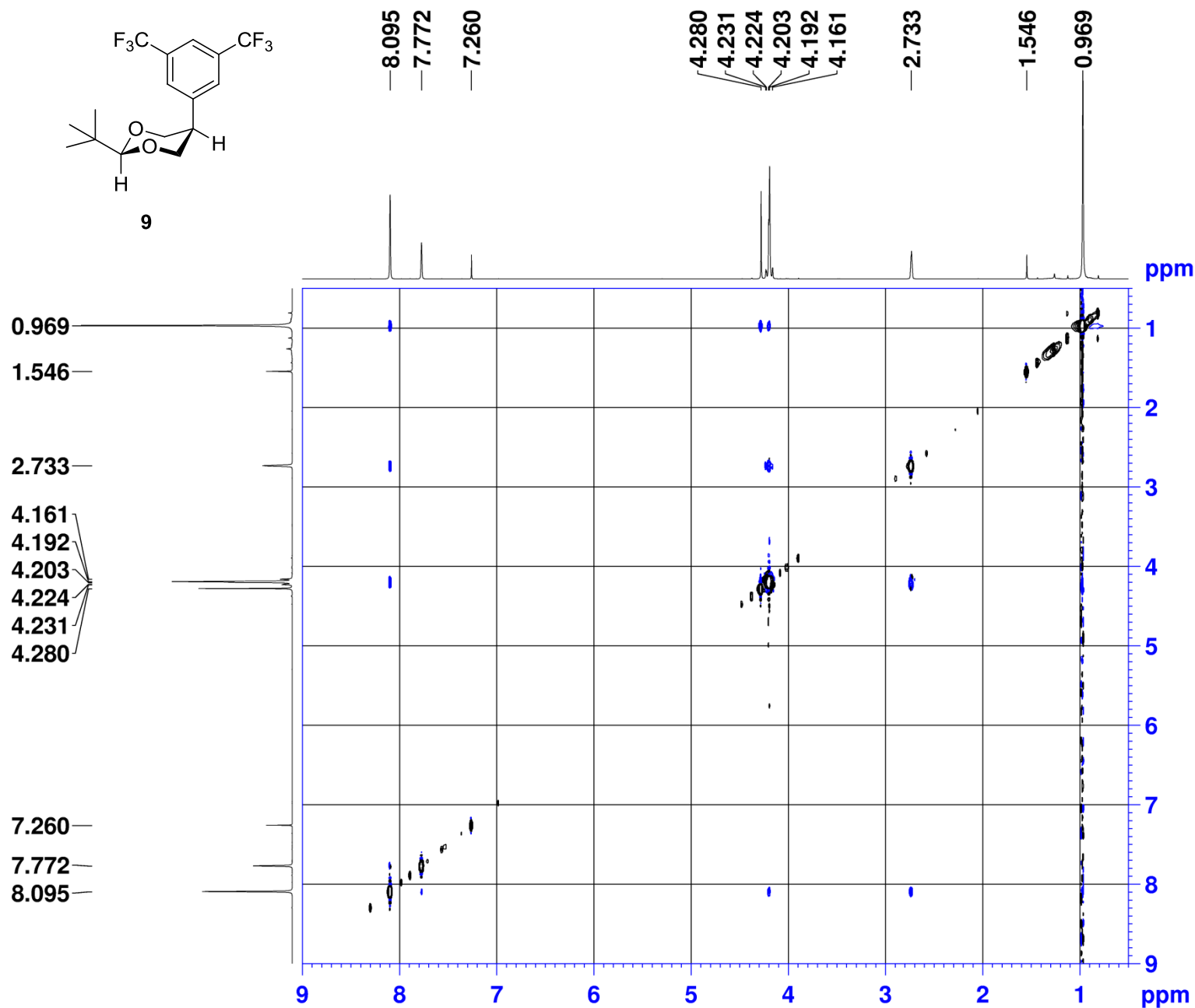
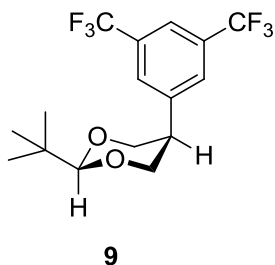
===== CHANNEL f1 =====
SFO1 376.4738882 MHz
NUC1 19F
P1 14.00 usec
PLW1 18.00000000 W

F2 - Processing parameters
SI 65536
SF 376.5115529 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

— -62.84

-113.11
-113.13
-113.14
-113.15
-113.17
-113.18
-113.19





Current Data Parameters
 NAME kl-2-189-axial%3F 1HNOESY
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20150721
 Time 21.32
 INSTRUM spect
 PROBHD 5 mm PABBO BB/
 PULPROG noesygpphpp
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 32
 SWH 4084.967 Hz
 FIDRES 1.994613 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 D0 0.00010330 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec

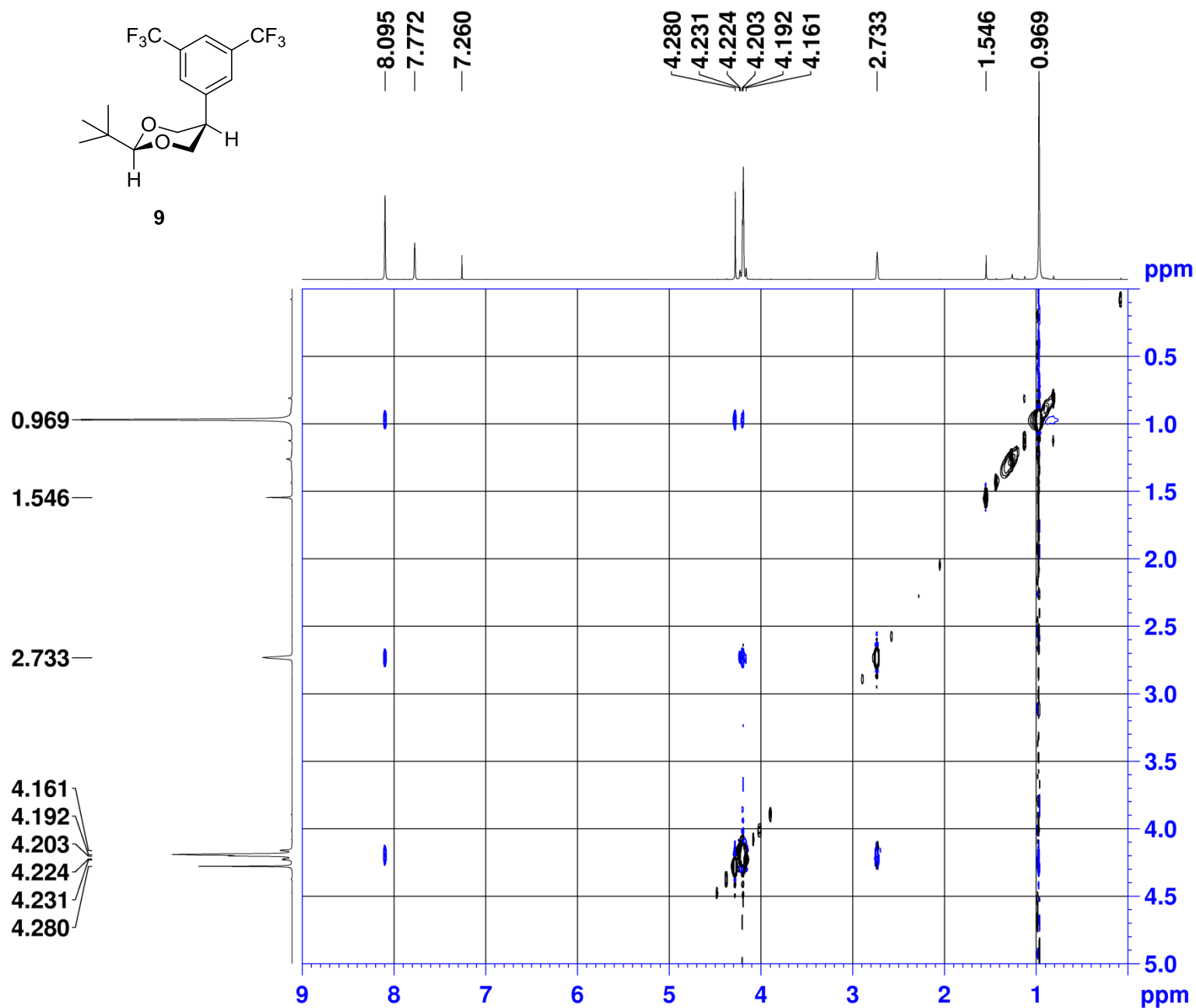
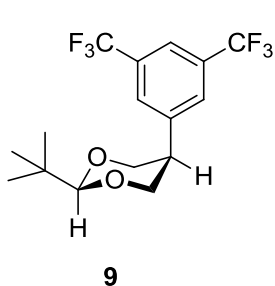
===== CHANNEL f1 =====
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.00 usec
 P2 30.00 usec
 P17 2500.00 usec
 PLW1 12.00000000 W
 PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FnmODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440079 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 FC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440079 MHz
 WDW
 SSB 2
 LB 0 Hz
 GB 0



Current Data Parameters
 NAME kl-2-189-axial%3F 1HNOESY
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20150721
 Time 21.32
 INSTRUM spect
 PROBHD 5 mm PABBO BB/
 PULPROG noesygpph
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 32
 SWH 4084.967 Hz
 FIDRES 1.994613 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 D0 0.00010330 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec

===== CHANNEL f1 =====
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.00 usec
 P2 30.00 usec
 P17 2500.00 usec
 PLW1 12.00000000 W
 PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FnmODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440079 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 FC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440079 MHz
 WDW
 SSB 2
 LB 0 Hz
 GB 0



Current Data Parameters
NAME kl-2-189-axial3F HSQC
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150721
Time 21.09
INSTRUM spect
PROBHD 5 mm PARBO BB/
PULPROG hsqcetgpsi2.3
TD 1024
SOLVENT CDCl3
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNS2 145.000000
CNS17 -0.5000000
D0 0.00000300 sec
D1 1.00000000 sec
D4 0.00172414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.00360000 sec
D24 0.00089000 sec
IN0 0.00003010 sec

===== CHANNEL f1 =====
SFO1 400.1458907 MHz
NUC1 13
P1 15.25 usec
P2 30.50 usec
P28 1000.00 usec
PLW1 12.00000000 W

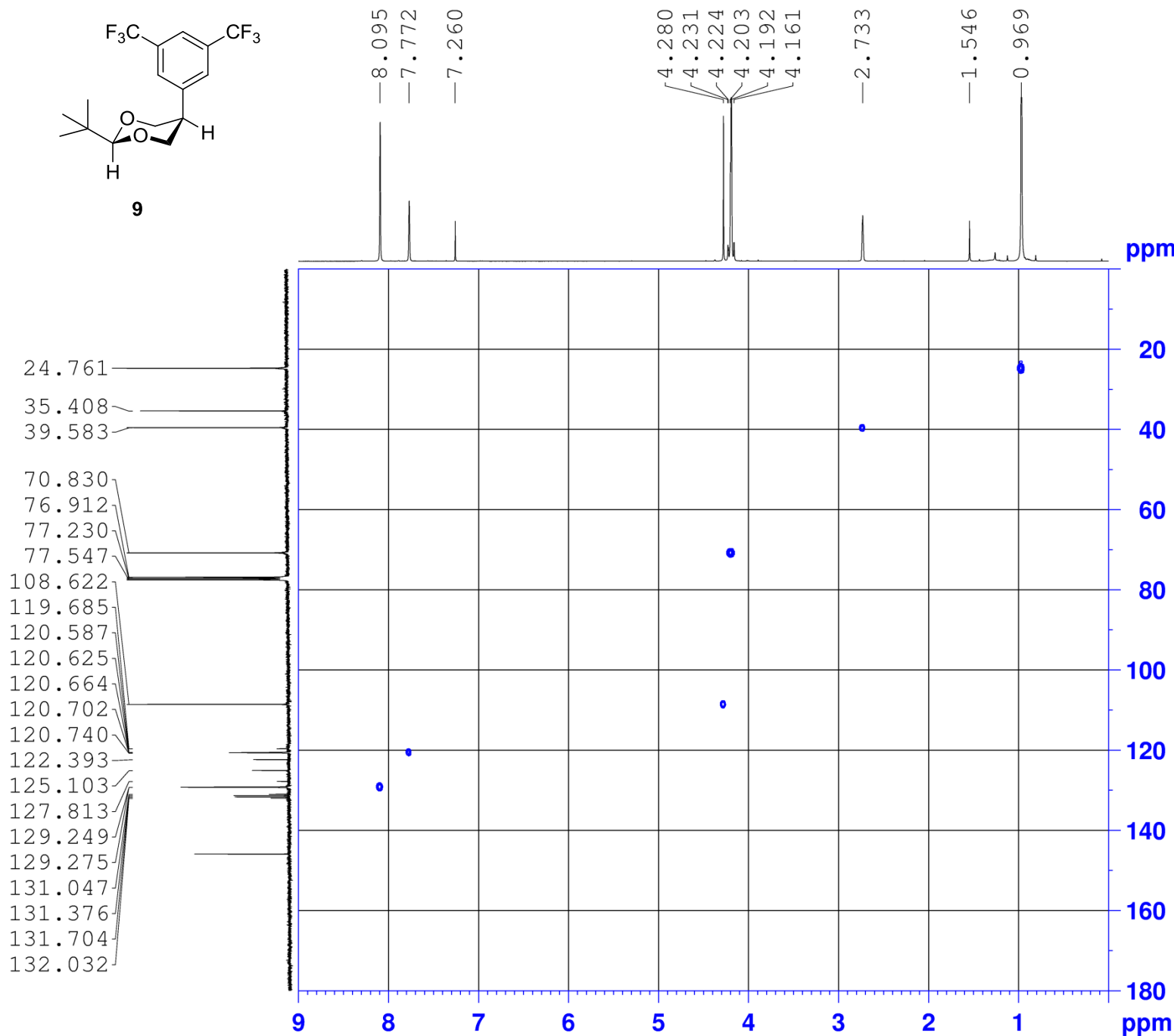
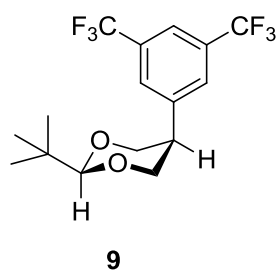
===== CHANNEL f2 =====
SFO2 100.6233320 MHz
NUC2 13C
CPDPRG2 2 bl_p5m4sp_4sp.2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1900.00 usec
P63 1500.00 usec
PLW0 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SFOAL3 0.500
SPOFFS3 0 Hz
SPW3 SPNAM[7] Crp60decp.4
SFOAL7 0.500
SPOFFS7 0 Hz
SPW7 SPNAM[14] Crp32,1.5,20.2
SFOAL14 0.500
SPOFFS14 0 Hz
SPW14 SPNAM[18] Crp60_kfilt.2
SFOAL18 0.500
SPOFFS18 0 Hz
SPW18 SPNAM[31] Crp32,1.5,20.2
SFOAL31 0.500
SPOFFS31 0 Hz
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPNAM[3] SMSQ10.100
GPNAM[4] SMSQ10.100
GP21 80.00 %
GP22 20.10 %
GP23 11.00 %
GP24 5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 128
SFO1 100.6233 MHz
FIDRES 129.775742 Hz
SW 165.084 ppm
FMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440066 MHz
WDW QSI
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162650 MHz
WDW States
SSB 2
LB 0 Hz
GB 0



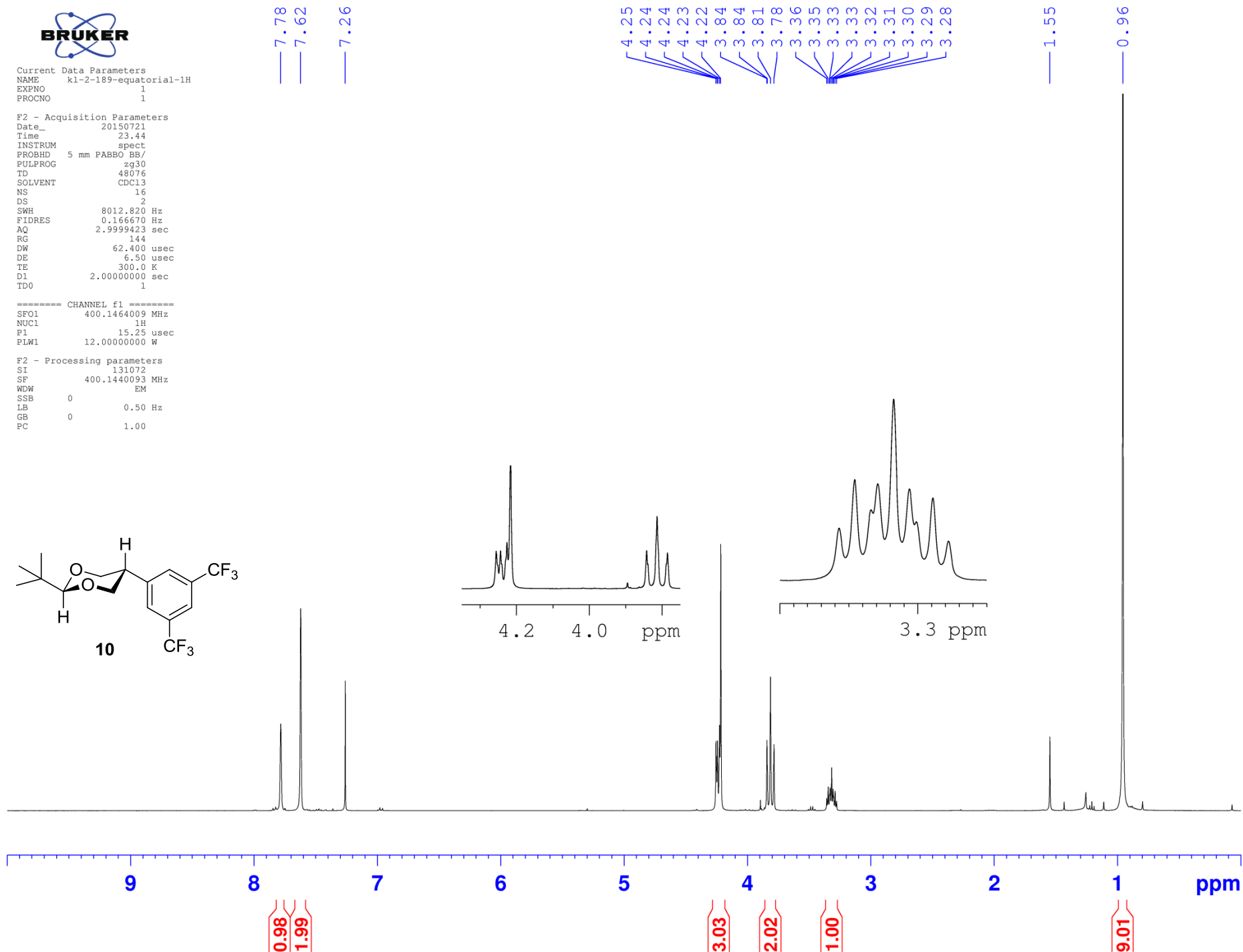
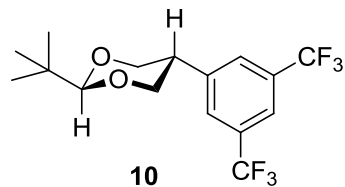


Current Data Parameters
NAME k1-2-189-equatorial-1H
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150721
Time 23.44
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 144
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440093 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00





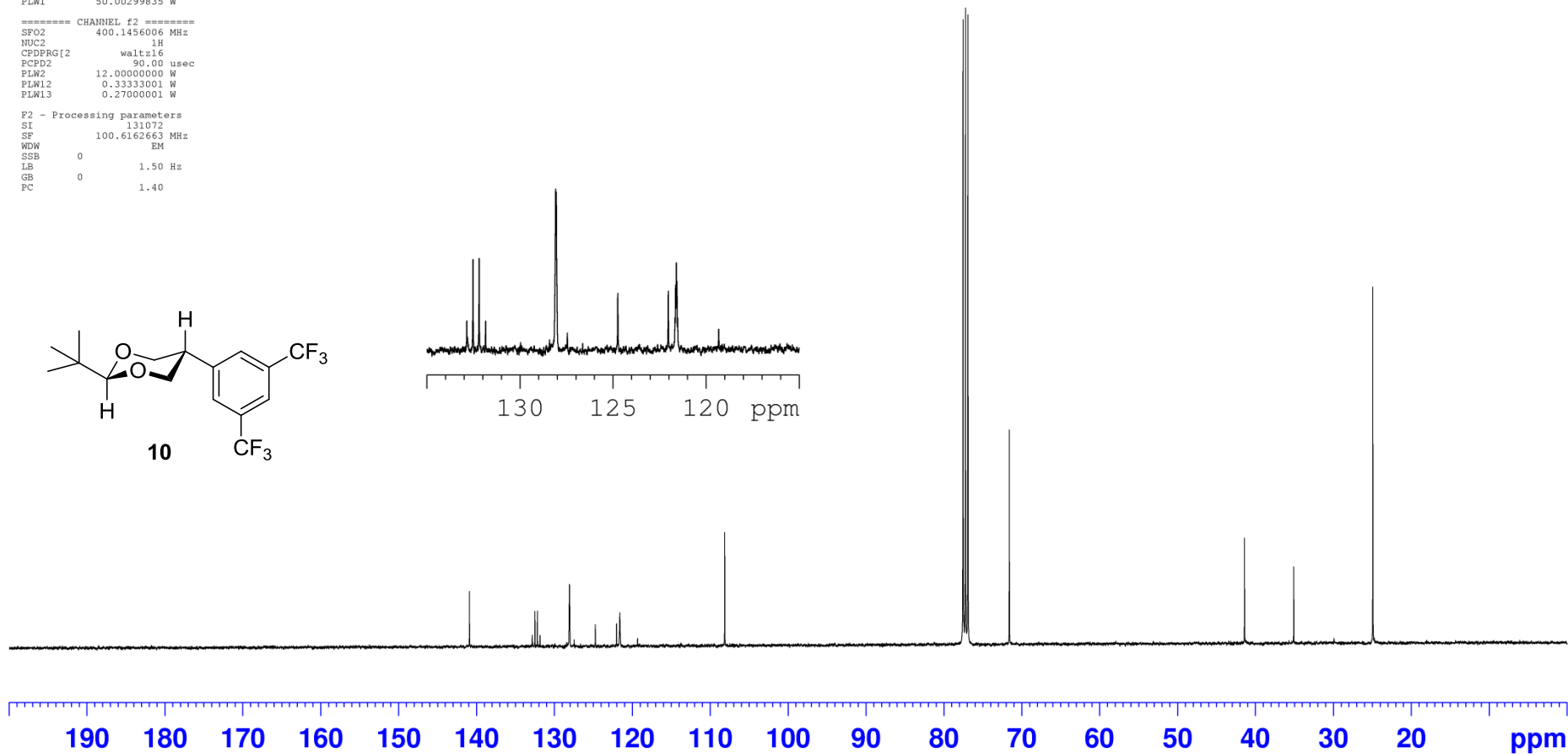
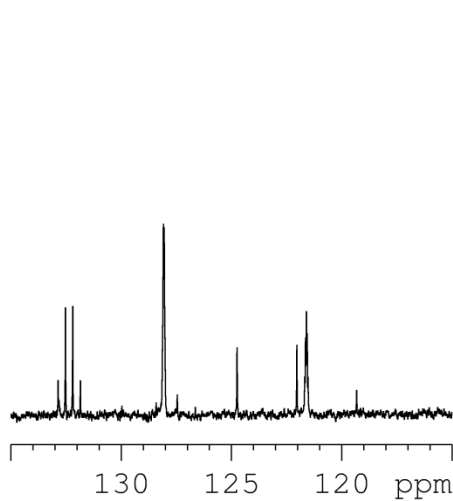
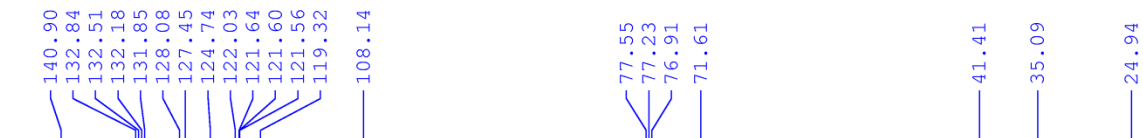
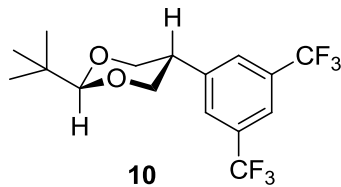
Current Data Parameters
NAME kl-2-189-equatorial-13C
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150722
Time 1.43
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 2820
DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
AQ 0.8652204 sec
RG 203
DW 19.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162663 MHz
WDW EM
SSB 0
LB 1.50 Hz
GB 0
PC 1.40





Current Data Parameters
NAME kl-2-189-equatorial-F19
EXPNO 1
PROCNO 1

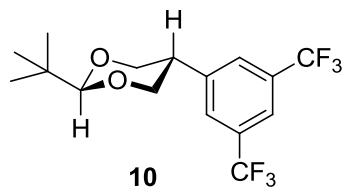
F2 - Acquisition Parameters
Date_ 20150722
Time 3.35
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 131072
SOLVENT CDCl3
NS 8
DS 4
SWH 89285.711 Hz
FIDRES 0.681196 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 1.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 376.4738882 MHz
NUC1 19F
P1 14.00 usec
PLW1 18.00000000 W

F2 - Processing parameters
SI 65536
SF 376.5115590 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

— -62.99

— -113.15
— -113.17



-20

-40

-60

-80

-100

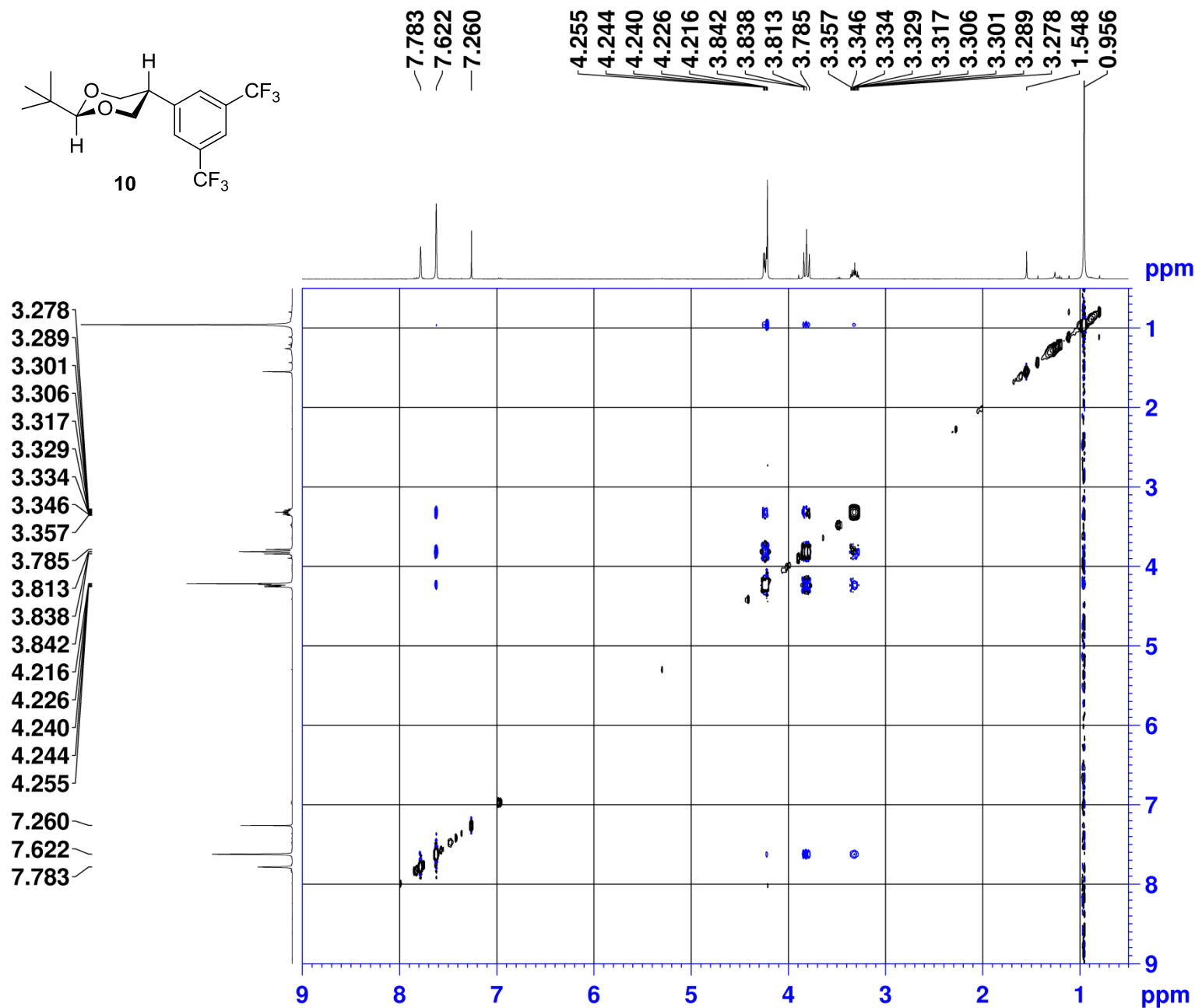
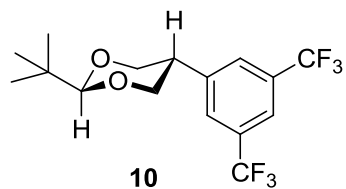
-120

-140

-160

-180

ppm



Current Data Parameters
 NAME k1-2-189-equatorial-HNOESY
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20150722
 Time 2.15
 INSTRUM spect
 PROBHD 5 mm PABBO BB/
 PULPROG noesygpphph
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 32
 SWH 4084.967 Hz
 FIDRES 1.994613 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 D0 0.00010330 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec

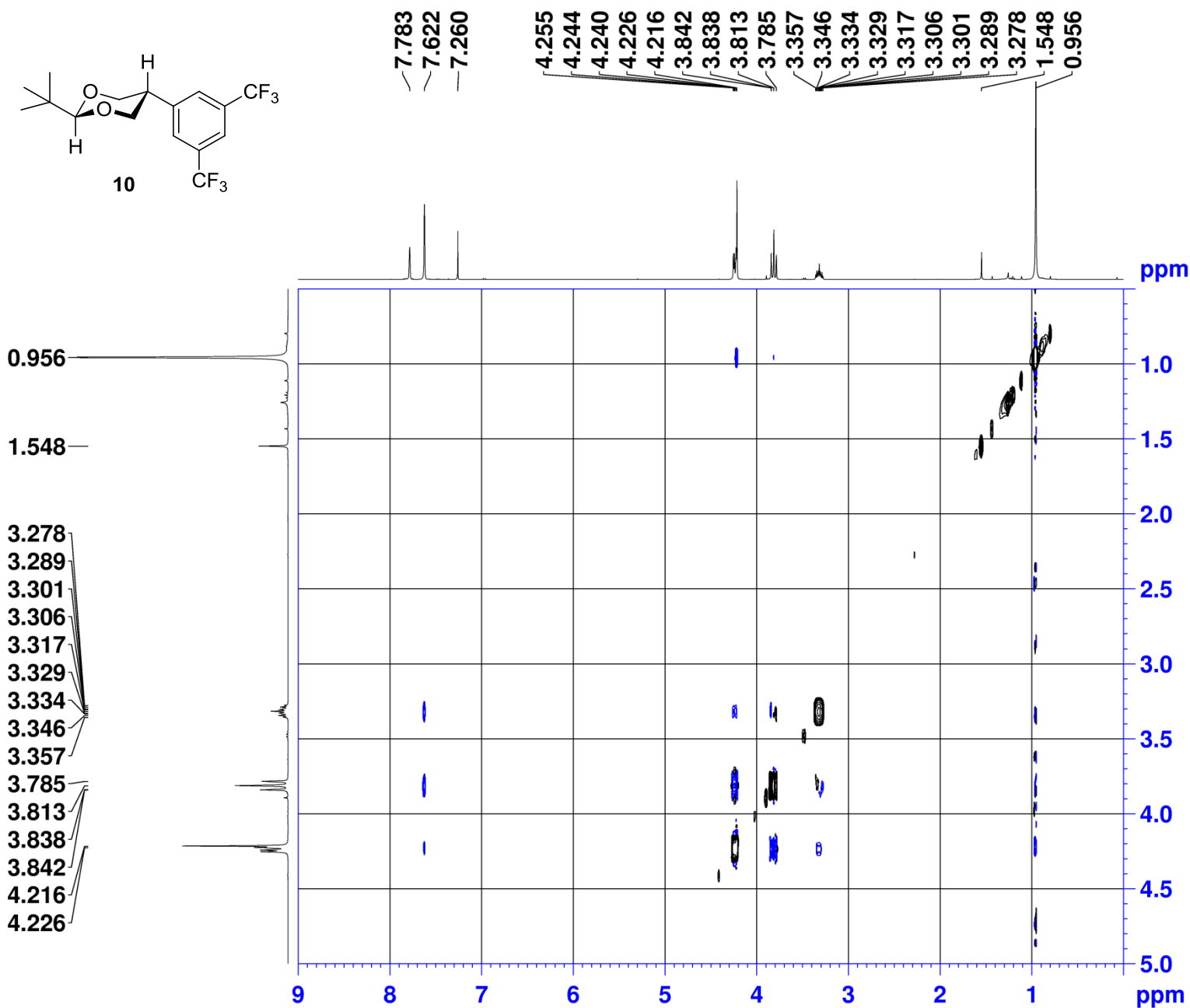
===== CHANNEL f1 =====
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.00 usec
 P2 30.00 usec
 P17 2500.00 usec
 PLW1 12.00000000 W
 PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
 GPNAM[1] SMSQ10.100
 GP21 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FnmODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440079 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 FC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440079 MHz
 WDW
 SSB 2
 LB 0 Hz
 GB 0



Current Data Parameters
 NAME kl-2-189-equatorial-HNOESY
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20150722
 Time 2.15
 INSTRUM spect
 PROBHD 5 mm PABBO BB/
 PULPROG noesygpphpp
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 32
 SWH 4084.967 Hz
 FIDRES 1.994613 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 D0 0.00010330 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec

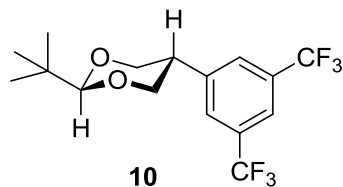
===== CHANNEL f1 =====
 SF01 400.1458419 MHz
 NUC1 1H
 P1 15.00 usec
 P2 30.00 usec
 P17 2500.00 usec
 PLW1 12.00000000 W
 PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SF01 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FMODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440079 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 FC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440079 MHz
 WDW
 SSB 2
 LB 0 Hz
 GB 0

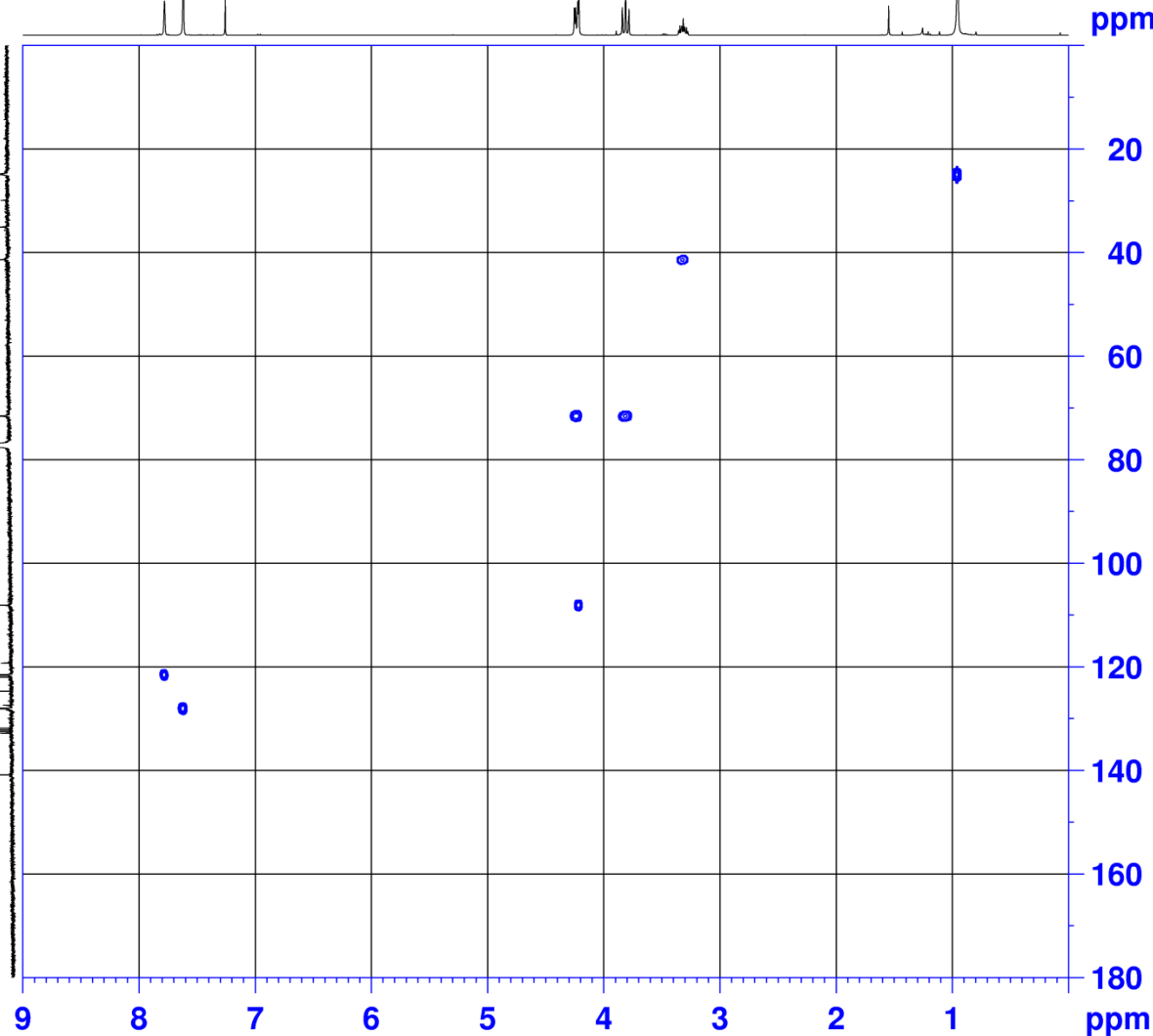


~7.783
~7.622
~7.260

4.255
4.244
4.240
4.226
4.216
3.842
3.838
3.813
3.785
3.357
3.346
3.334
3.329
3.317
3.306
3.301
3.289
3.278
1.548
0.956

24.936
35.092
41.405

71.607
76.912
77.230
77.547
108.135
119.321
121.564
121.601
121.639
122.031
124.743
127.453
128.077
131.846
132.177
132.508
132.839
140.904



Current Data Parameters
NAME kl-2-189-equatorial-HSQC
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150122
Time 1.48
INSTRUM spect
PROBHD 5 mm PARBO BB
PULPROG haqcetdgpasp2.3
TD 1024
SOLVENT CDCl3
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNS12 145.000000
CNS17 -0.5000000
D0 0.00000300 sec
D1 1.00000000 sec
D4 0.00172414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.00360000 sec
D24 0.00089000 sec
IN0 0.00003010 sec

===== CHANNEL f1 =====
SFO1 400.1458907 MHz
NUC1 13
P1 15.25 usec
P2 30.50 usec
P28 1000.00 usec
PLW1 12.00000000 W

===== CHANNEL f2 =====
SFO2 100.6233320 MHz
NUC2 13C
CPDPRG2 bl_p5m4sp_4sp.2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1900.00 usec
P63 1500.00 usec
PLW0 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SPOAL3 0.500
SPOFFS3 0 Hz
SPW1 SPNAM[7] 7.63940001 W
SPOAL7 Crp60,0.5,20.1
SPOFFS7 0 Hz
SPW7 7.63940001 W
SPNAM[14] Crp32,1.5,20.2
SPOAL14 0.500
SPOFFS14 0 Hz
SPW14 3.25950003 W
SPNAM[18] Crp60_kfilt.2
SPOAL18 0.500
SPOFFS18 0 Hz
SPW18 1.83050001 W
SPNAM[31] Crp32,1.5,20.2
SPOAL31 0.500
SPOFFS31 0 Hz
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPNAM[3] SMSQ10.100
GPNAM[4] SMSQ10.100
GP21 80.00 %
GP22 20.10 %
GP23 11.00 %
GP24 5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 128
SFO1 100.6233 MHz
FIDRES 129.775742 Hz
SW 165.084 ppm
FMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440078 MHz
WDW QSI
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162588 MHz
WDW States
SSB 2
LB 0 Hz
GB 0

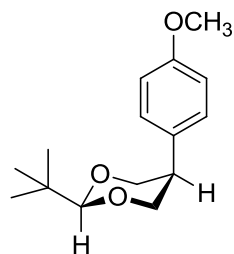


Current Data Parameters
NAME kl-1-124-axial-H1
EXPNO 1
PROCNO 1

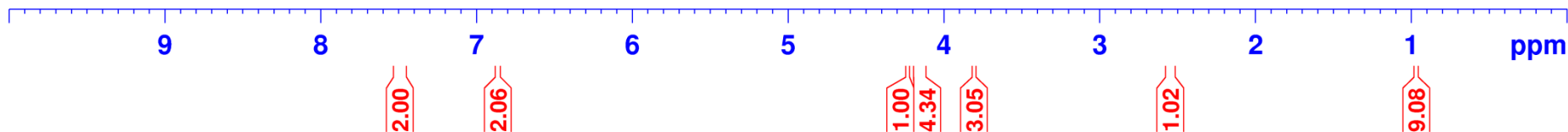
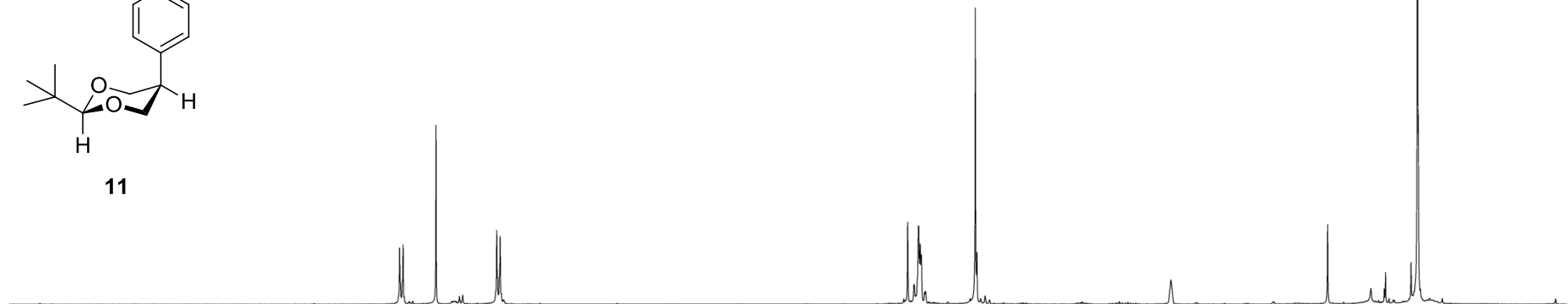
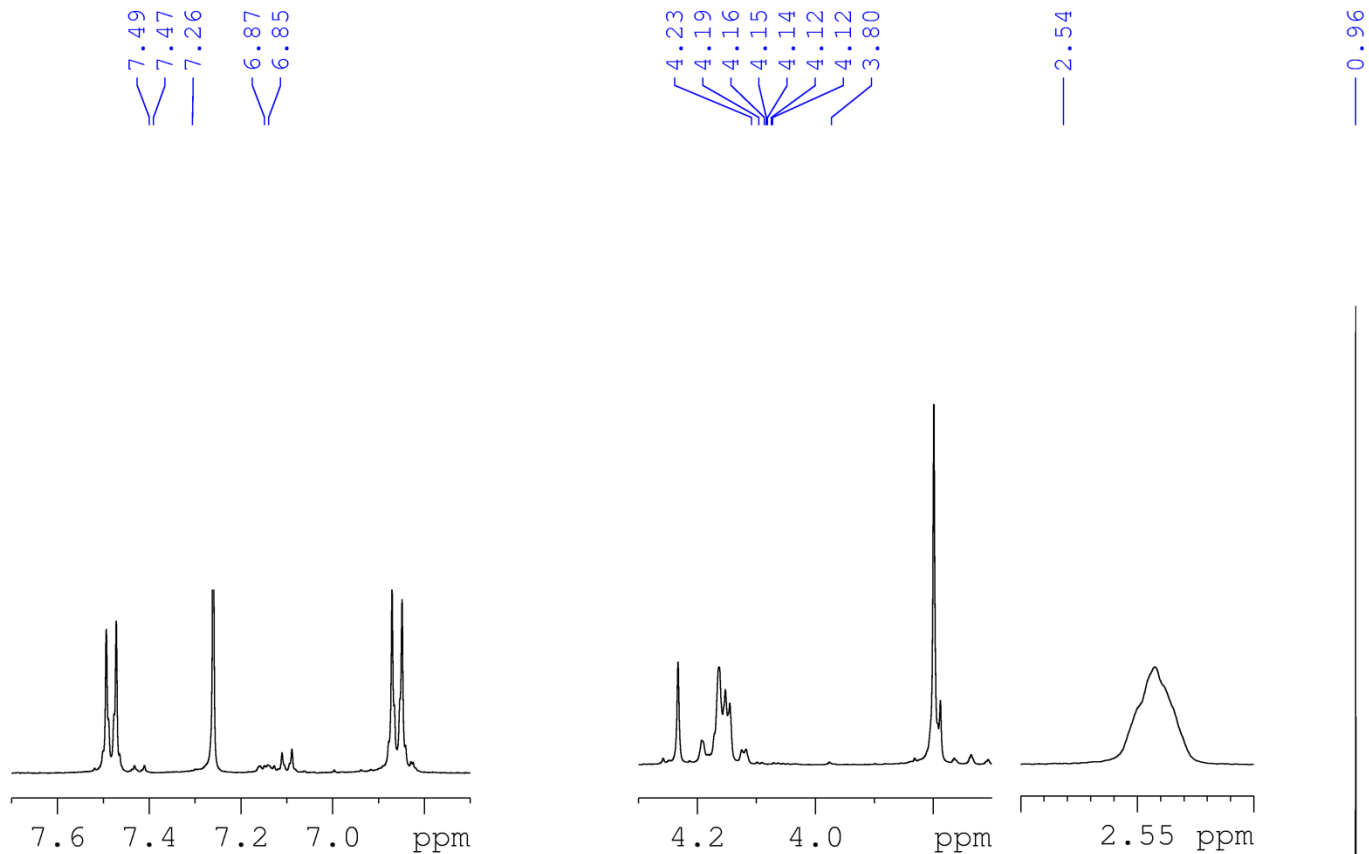
F2 - Acquisition Parameters
Date_ 20151029
Time 21.48
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 203
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440097 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00



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Current Data Parameters
NAME ki-1-124-axial-C13
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20151029
Time 22.20
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG udeft
TD 17368
SOLVENT CDCl3
NS 254
DS 0
SWH 24038.461 Hz
FIDRES 1.388864 Hz
AQ 0.3600064 sec
RG 203
DW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 4.00000000 sec
D11 0.03000000 sec
D12 0.00002000 sec
D20 200.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6273568 MHz
NUC1 13C
P1 10.00 usec
P13 2000.00 usec
P26 500.00 usec
PLW1 50.00299835 W
SPNAM[5] Crp60comp,4
SFOAL5 0 Hz
SPOFFS5 0 Hz
SPW5 7.63990021 W
SPNAM[8] Crp60,0.5,20.1
SFOAL8 0 Hz
SPOFFS8 0 Hz
SPW8 7.63990021 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CDDPRG[2] waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W

F2 - Processing parameters
SI 131072
SF 100.6162672 MHz
WCHW 2K
SSB 0
LA 2.00 Hz
GB 0
PC 1.40

— 158.35

— 136.05

— 129.72

— 113.81

— 108.35

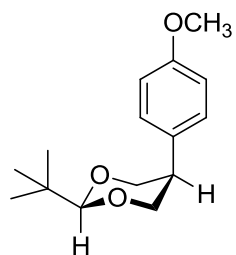
77.55
77.23
76.91
71.73

— 55.47

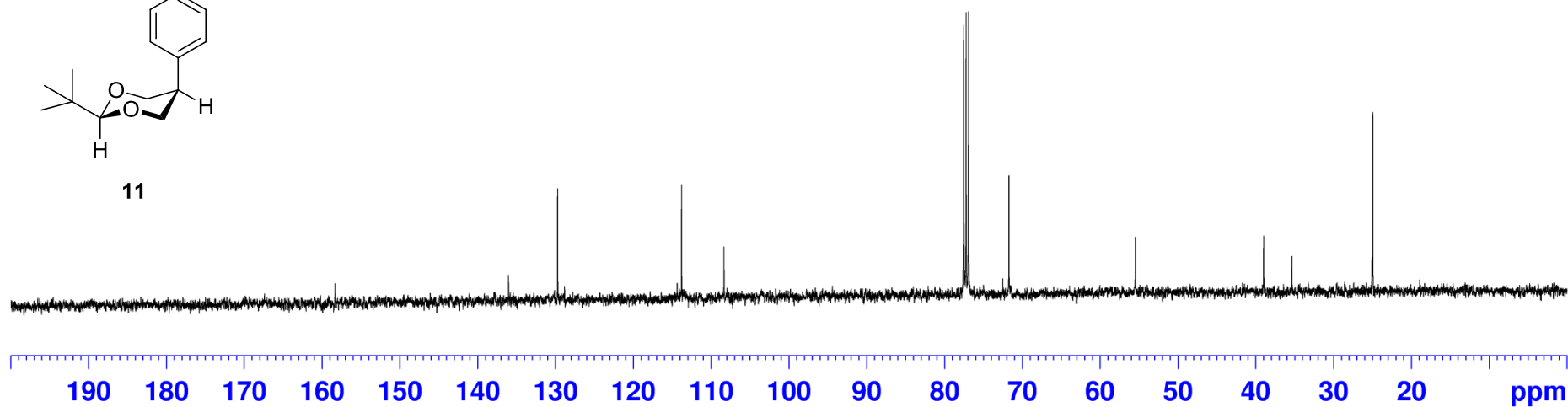
— 38.99

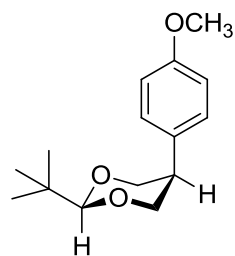
— 35.35

— 24.96

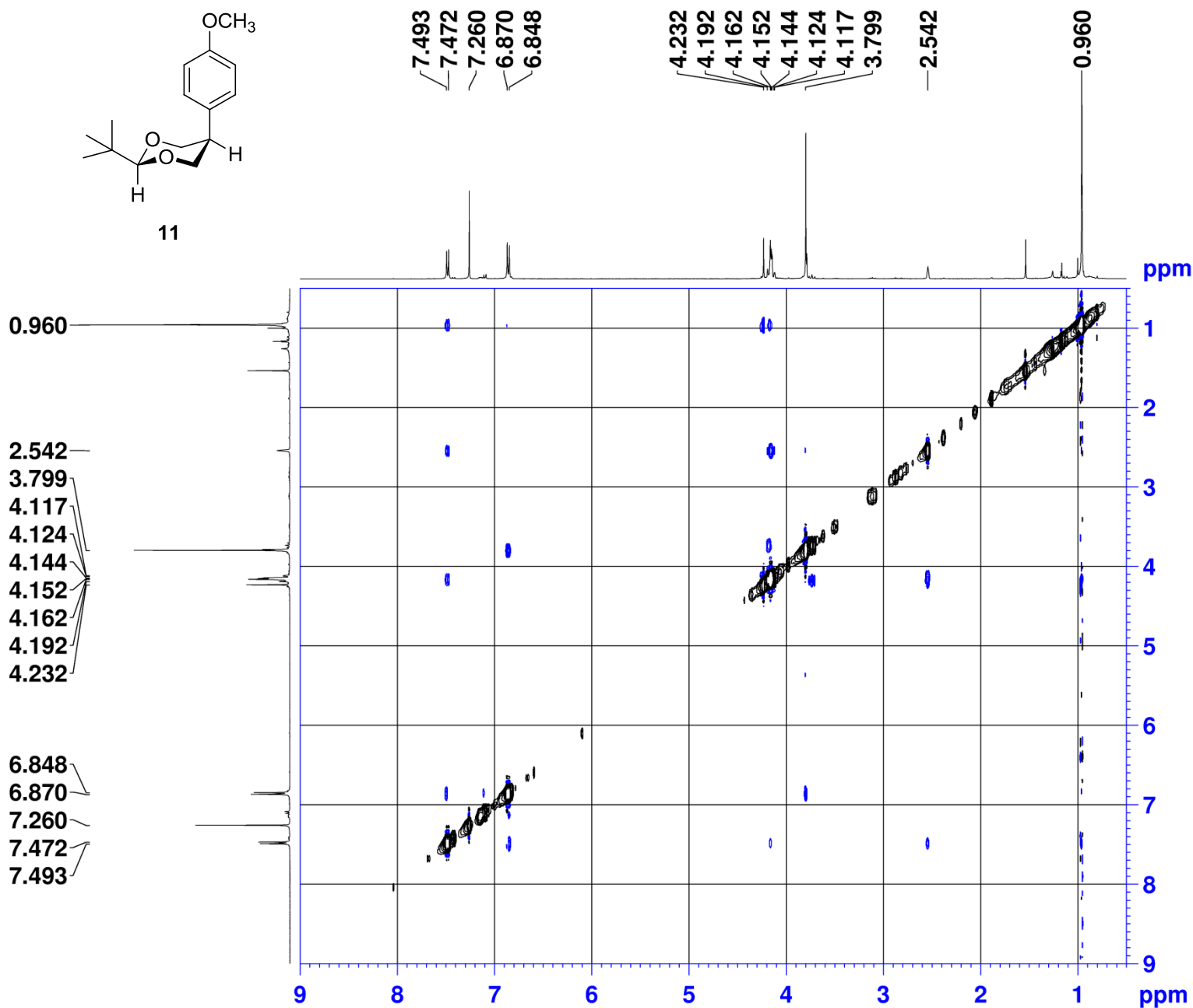


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11



Current Data Parameters
NAME kl-1-124-axial-HNOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20151029
Time 22.55
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphph
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

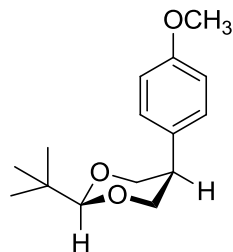
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

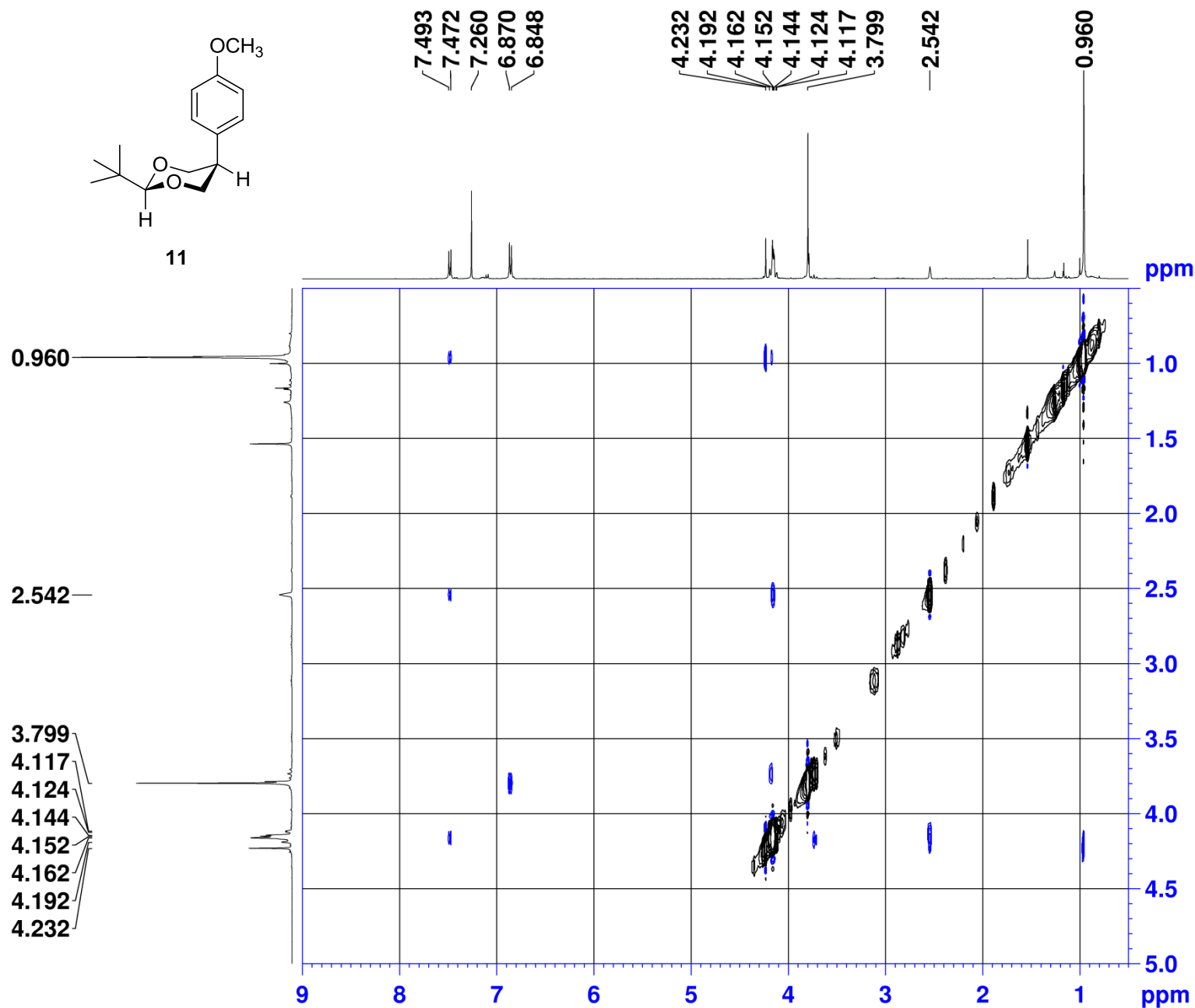
F1 - Acquisition parameters
TD 168
SFO1 400.1458 MHz
FIDRES 24.315281 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440084 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440083 MHz
WDW
SSB 2
LB 0 Hz
GB 0



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Current Data Parameters
NAME kl-1-124-axial-HNOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20151029
Time 22.55
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphpp
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

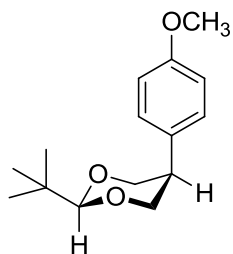
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

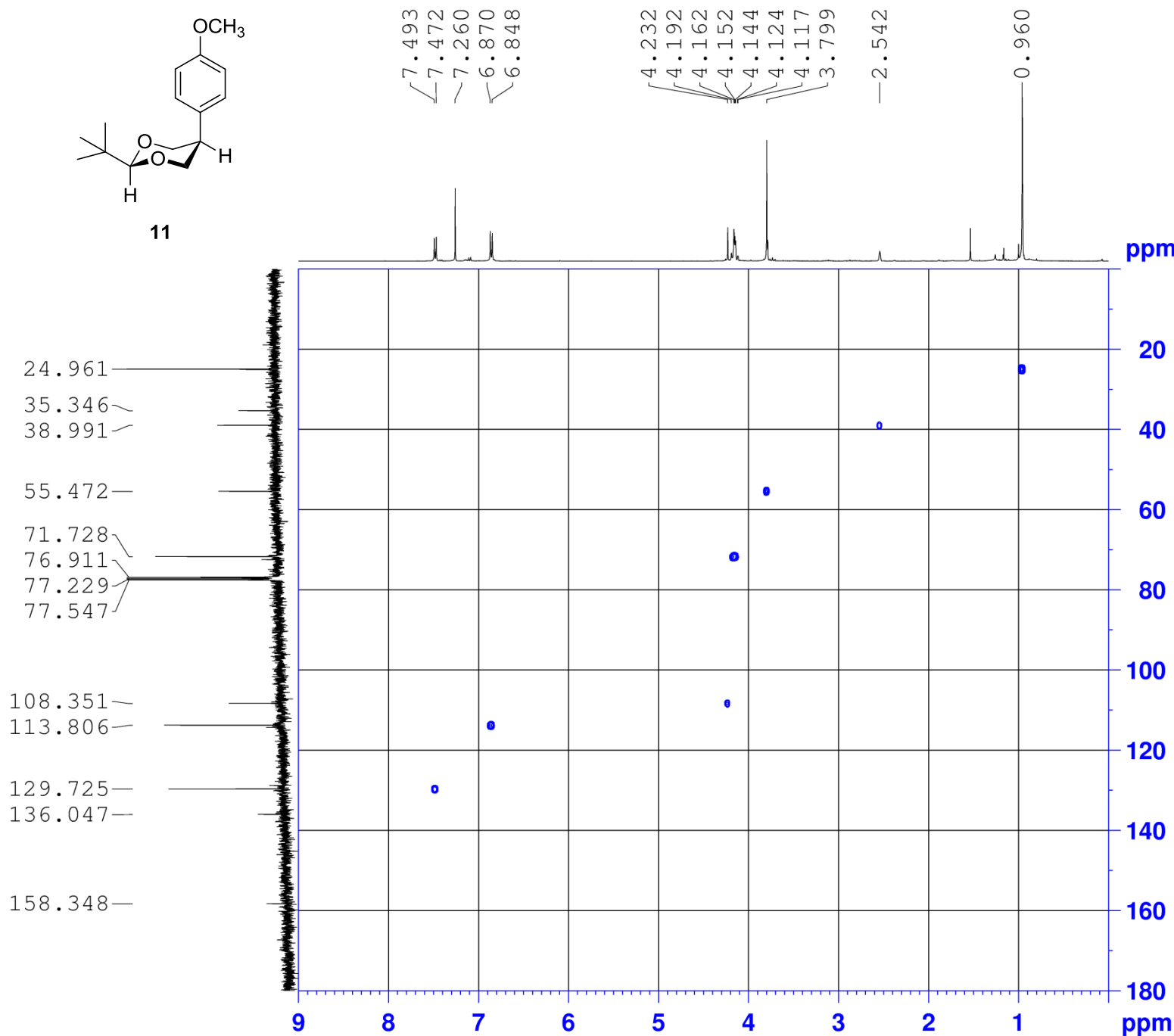
F1 - Acquisition parameters
TD 168
SFO1 400.1458 MHz
FIDRES 24.315281 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440084 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440083 MHz
WDW
SSB 2
LB 0 Hz
GB 0



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Current Data Parameters
NAME kl-1-124-axial-HSQC
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20131028
Time 22.23
INSTRUM spect
PROBHD 5 mm PARBO BB/
PULPROG hsqcetgpsisp2.3
TD 1024
SOLVENT CDCl3
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNS12 145.000000
CNS17 -0.5000000
D0 0.00000300 sec
D1 1.00000000 sec
D4 0.00172414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.00360000 sec
D24 0.00089000 sec
IN0 0.00003010 sec

===== CHANNEL f1 =====
SFO1 400.1458907 MHz
NUC1 13
P1 15.25 usec
P2 30.50 usec
P28 1000.00 usec
PLW1 12.00000000 W

===== CHANNEL f2 =====
SFO2 100.6233320 MHz
NUC2 13C
CPDPRG2 2 bl_p5m4sp_4sp.2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1900.00 usec
P63 1500.00 usec
PLW0 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SFOAL3 0.500
SPOFFS3 0 Hz
SPW3 SPNAM[7] 7.63940001 W
SFOAL7 Crp60,0.5,20.1
SPOFFS7 0 Hz
SPW7 SPNAM[14] 7.63940001 W
SFOAL14 Crp32,1.5,20.2
SPOFFS14 0 Hz
SPW14 SPNAM[18] 3.25950003 W
SFOAL18 Crp60,0.5,20.1
SPOFFS18 0 Hz
SPW18 SPNAM[31] 1.83050001 W
SFOAL31 Crp32,1.5,20.2
SPOFFS31 0 Hz
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPNAM[3] SMSQ10.100
GPNAM[4] SMSQ10.100
GP21 80.00 %
GP22 20.10 %
GP23 11.00 %
GP24 5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 128
SFO1 100.6233 MHz
FIDRES 129.775742 Hz
SW 165.084 ppm
FMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440063 MHz
WDW QSI
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162602 MHz
WDW QSI
SSB 2
LB 0 Hz
GB 0

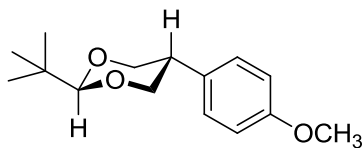


Current Data Parameters
NAME kl-1-124-equatorial-H1-B
EXPNO 1
PROCNO 1

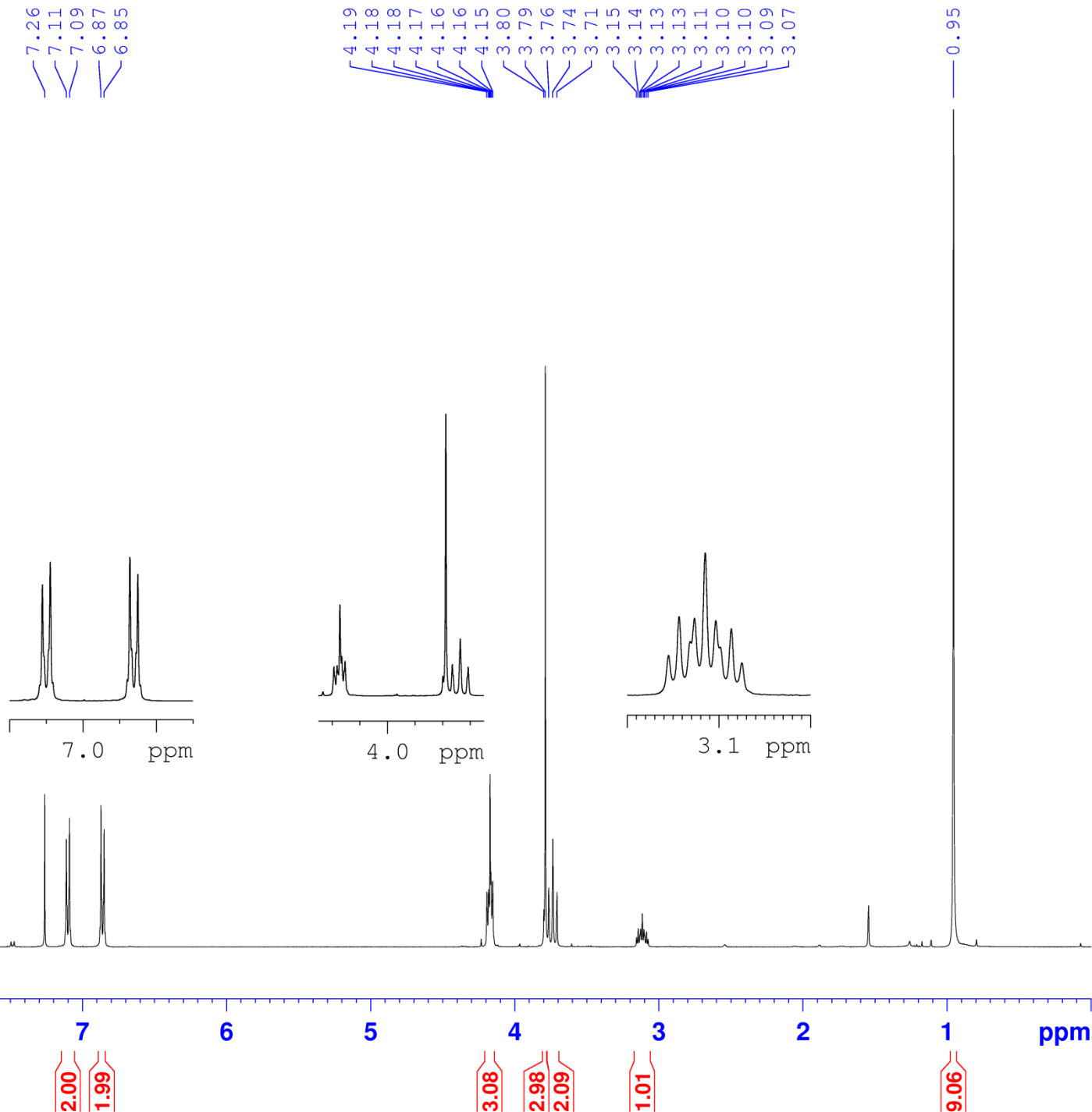
F2 - Acquisition Parameters
Date_ 20151029
Time 23.53
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 161
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440097 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00



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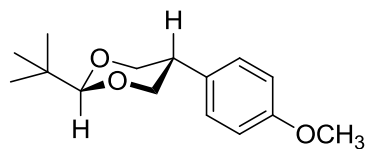
Current Data Parameters
NAME ki-1-124-equatorial-C13
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20151030
Time 0.02
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG udeft
TD 17368
SOLVENT CDCl3
NS 50
DS 0
SWH 24038.461 Hz
FIDRES 1.388864 Hz
AQ 0.3600064 sec
RG 203
DW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 4.00000000 sec
D11 0.03000000 sec
D12 0.00002000 sec
D20 200.00000000 sec
TDO 1

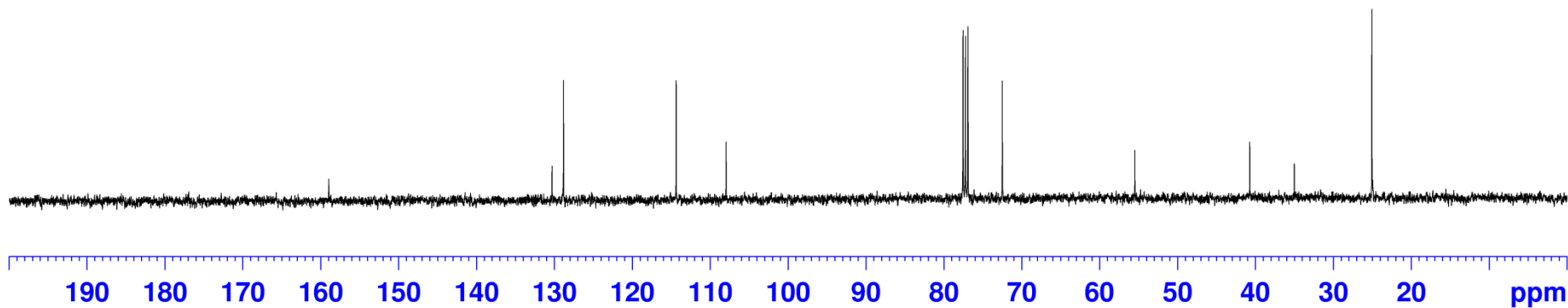
***** CHANNEL f1 *****
SFO1 100.6273568 MHz
NUC1 13C
P1 10.00 usec
P13 2000.00 usec
P26 500.00 usec
PLW1 50.00299835 W
SPNAM[5] Crp60comp,4
SFOAL5 0 Hz
SPOFFS5 0 Hz
SPW5 7.63990021 W
SPNAM[8] Crp60,0.5,20.1
SFOAL8 0 Hz
SPOFFS8 0 Hz
SPW8 7.63990021 W

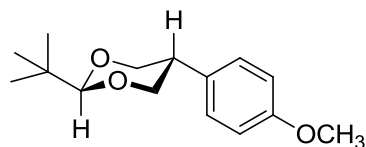
***** CHANNEL f2 *****
SFO2 400.1456006 MHz
NUC2 1H
CDDPRG[2] waltra16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W

F2 - Processing parameters
SI 131072
SF 100.6162673 MHz
WCHW BM
SSB 0
LA 2.00 Hz
GB 0
PC 1.40

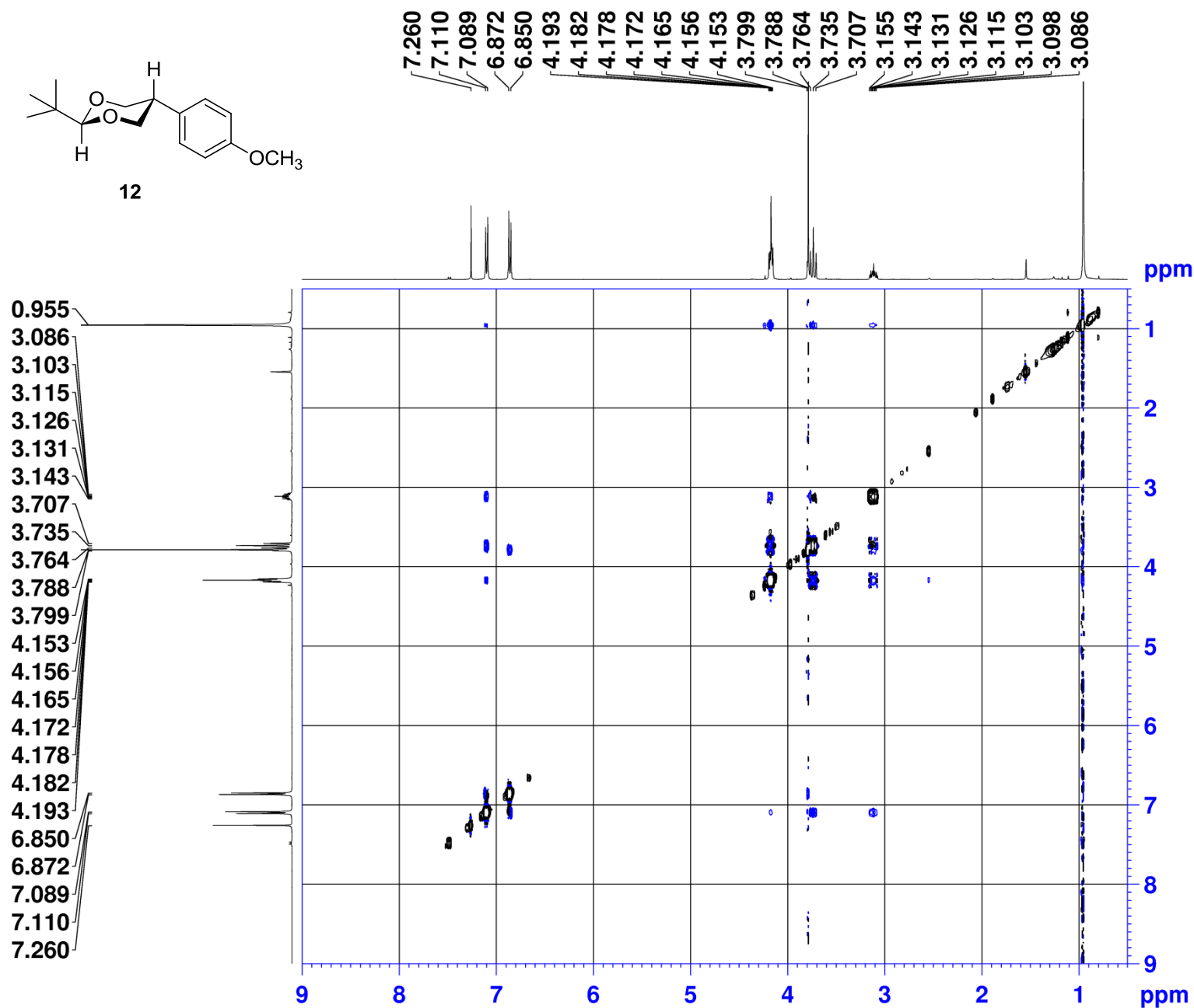


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Current Data Parameters
NAME kl-1-124-equatorial-HNOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20151030
Time 0.22
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphpp
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

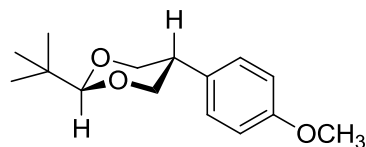
===== CHANNEL f1 =====
SF01 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

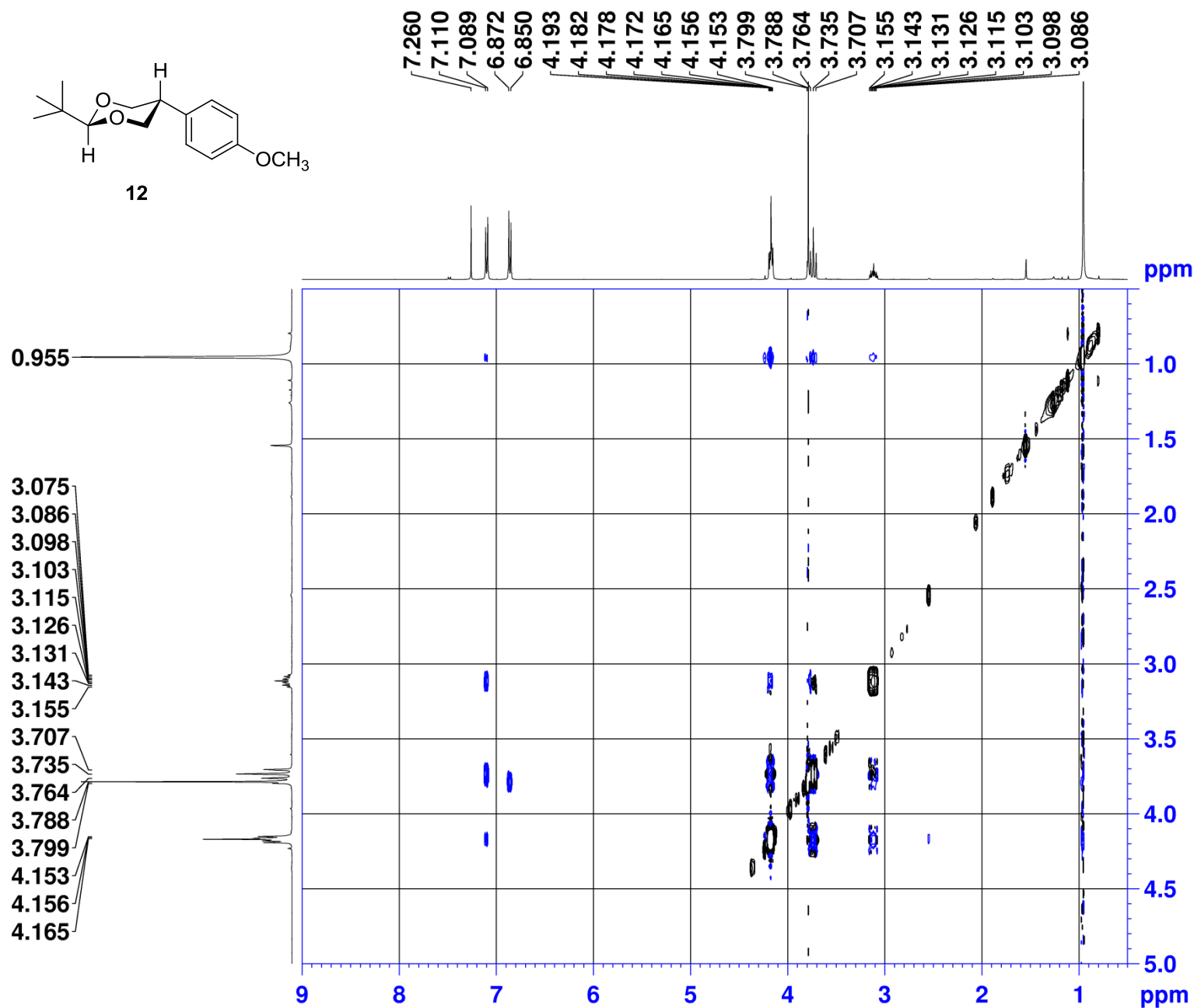
F1 - Acquisition parameters
TD 256
SF01 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440080 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440081 MHz
WDW
SSB 2
LB 0 Hz
GB 0



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Current Data Parameters
NAME kl-1-124-equatorial-HNOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20151030
Time 0.22
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpph
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

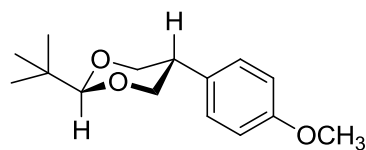
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

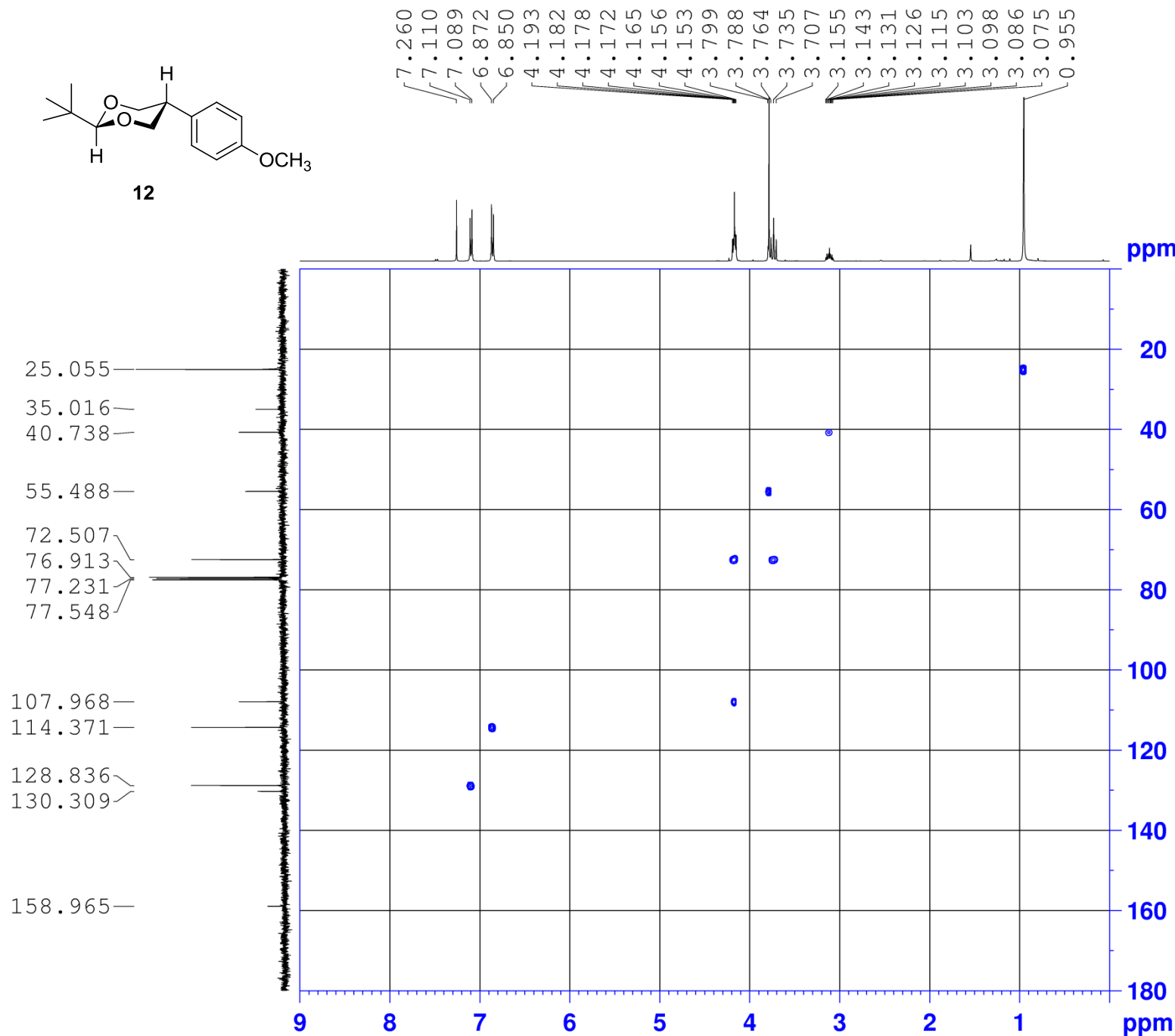
F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnmODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440080 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440081 MHz
WDW
SSB 2
LB 0 Hz
GB 0



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Current Data Parameters
NAME kl-1-124-equatorial-HSQC
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20131030
Time 0.04
INSTRUM spect
PROBHD 5 mm PARBO BB/
PULPROG hsqcetdetsps1p2.3
TD 1024
SOLVENT CDCl3
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNS2 145.000000
CNS17 -0.5000000
D0 0.00000300 sec
D1 1.00000000 sec
D4 0.00172414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.00360000 sec
D24 0.00089000 sec
IN0 0.00003010 sec

===== CHANNEL f1 =====
SFO1 400.1458907 MHz
NUC1 13
P1 15.25 usec
P2 30.50 usec
P28 1000.00 usec
PLW1 12.00000000 W

===== CHANNEL f2 =====
SFO2 100.6233320 MHz
NUC2 13C
CPDPRG2 2 bl_p5m4sp_4sp.2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1900.00 usec
P63 1500.00 usec
PLW0 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SFOAL3 0.500
SPOFFS3 0 Hz
SPW3 SPNAM[7] 7.63940001 W
SFOAL7 Crp60,0.5,20.1
SPOFFS7 0 Hz
SPW7 SPNAM[14] 7.63940001 W
SFOAL14 Crp32,1.5,20.2
SPOFFS14 0 Hz
SPW14 SPNAM[18] 3.25950003 W
SFOAL18 Crp60,0.5,20.1
SPOFFS18 0 Hz
SPW18 SPNAM[31] 1.83050001 W
SFOAL31 Crp32,1.5,20.2
SPOFFS31 0 Hz
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPNAM[3] SMSQ10.100
GPNAM[4] SMSQ10.100
GP21 80.00 %
GP22 20.10 %
GP23 11.00 %
GP24 5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 128
SFO1 100.6233 MHz
FIDRES 129.775742 Hz
SW 165.084 ppm
FMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440064 MHz
WDW QSI
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162581 MHz
WDW States
SSB 2
LB 0 Hz
GB 0

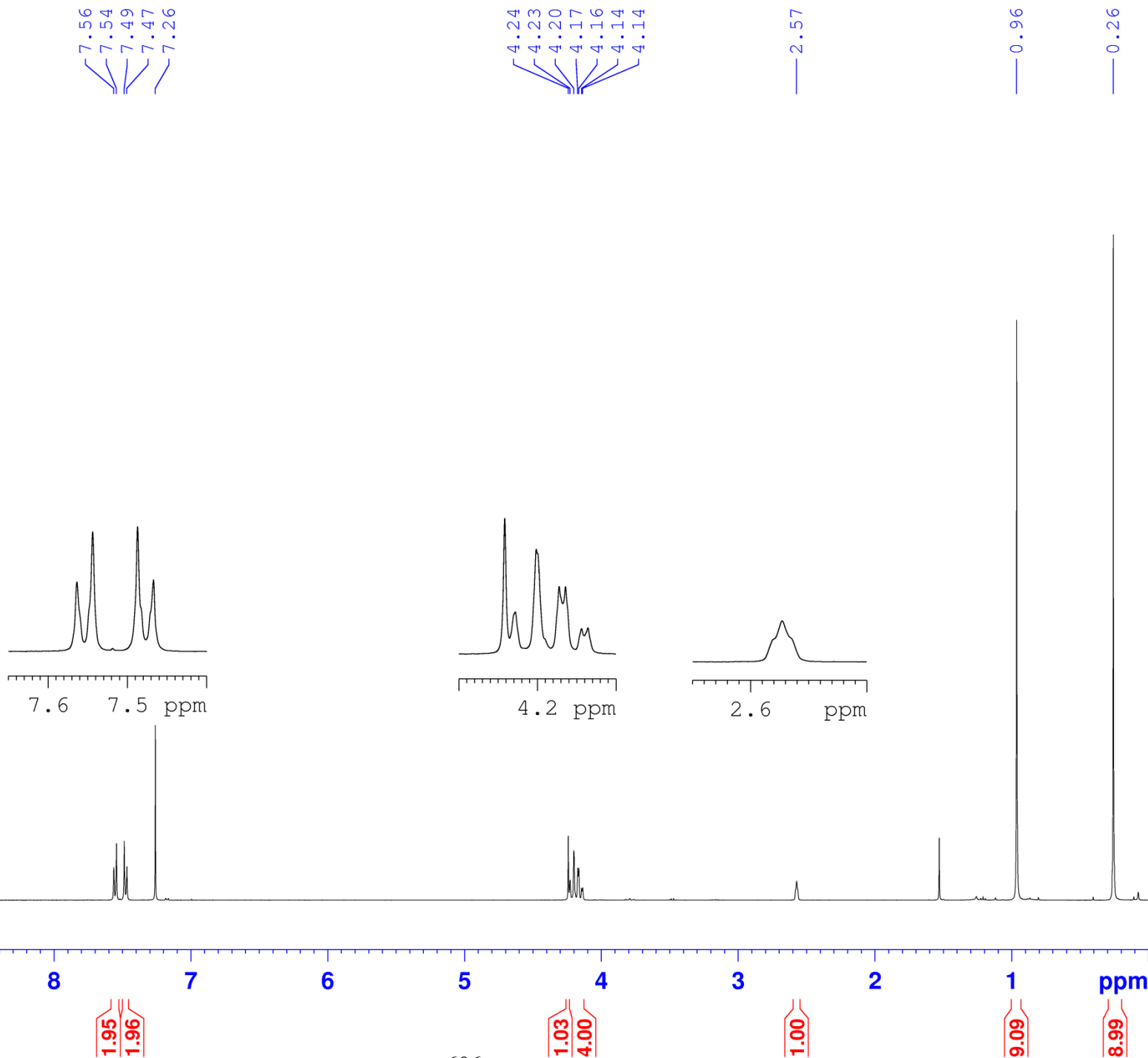
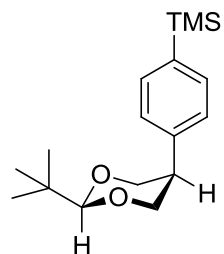


Current Data Parameters
NAME kl-2-203-axial H1
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20151008
Time 22.19
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 203
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440098 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00





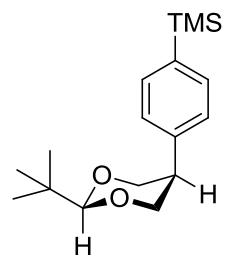
Current Data Parameters
NAME kl-2-203-c13
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20151008
Time 23.45
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG udeft
TD 17368
SOLVENT CDCl3
NS 755
DS 0
SWH 24038.461 Hz
FIDRES 1.388864 Hz
AQ 0.3600064 sec
RG 203
DW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 4.00000000 sec
D11 0.03000000 sec
D12 0.00002000 sec
D20 200.00000000 sec
TDO 1

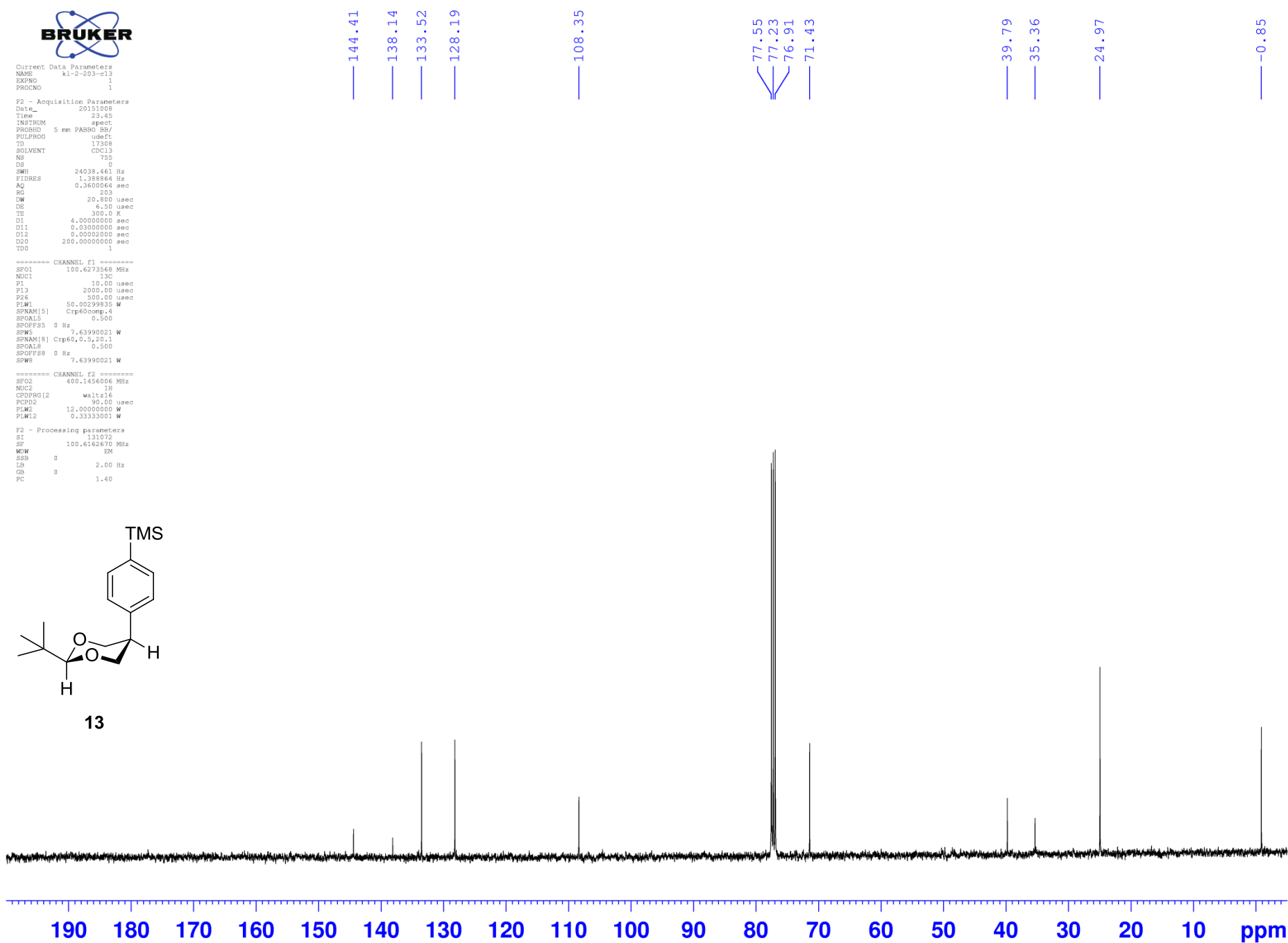
===== CHANNEL f1 =====
SFO1 100.6273568 MHz
NUC1 13C
P1 10.00 usec
P13 2000.00 usec
P26 500.00 usec
PLW1 50.00299835 W
SPNAM[5] Crp60comp,4
SFOAL5 0 Hz
SPOFFS5 0 Hz
SPW5 7.63990021 W
SPNAM[8] Crp60,0.5,20.1
SFOAL8 0 Hz
SPOFFS8 0 Hz
SPW8 7.63990021 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CDDPRG[2] waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W

F2 - Processing parameters
SI 131072
SF 100.6162670 MHz
WCHW 8K
SSB 0
LA 2.00 Hz
GB 0
PC 1.40



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Current Data Parameters
NAME k1-2-203-HNOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20151008
Time 23.49
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphpp
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 203
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

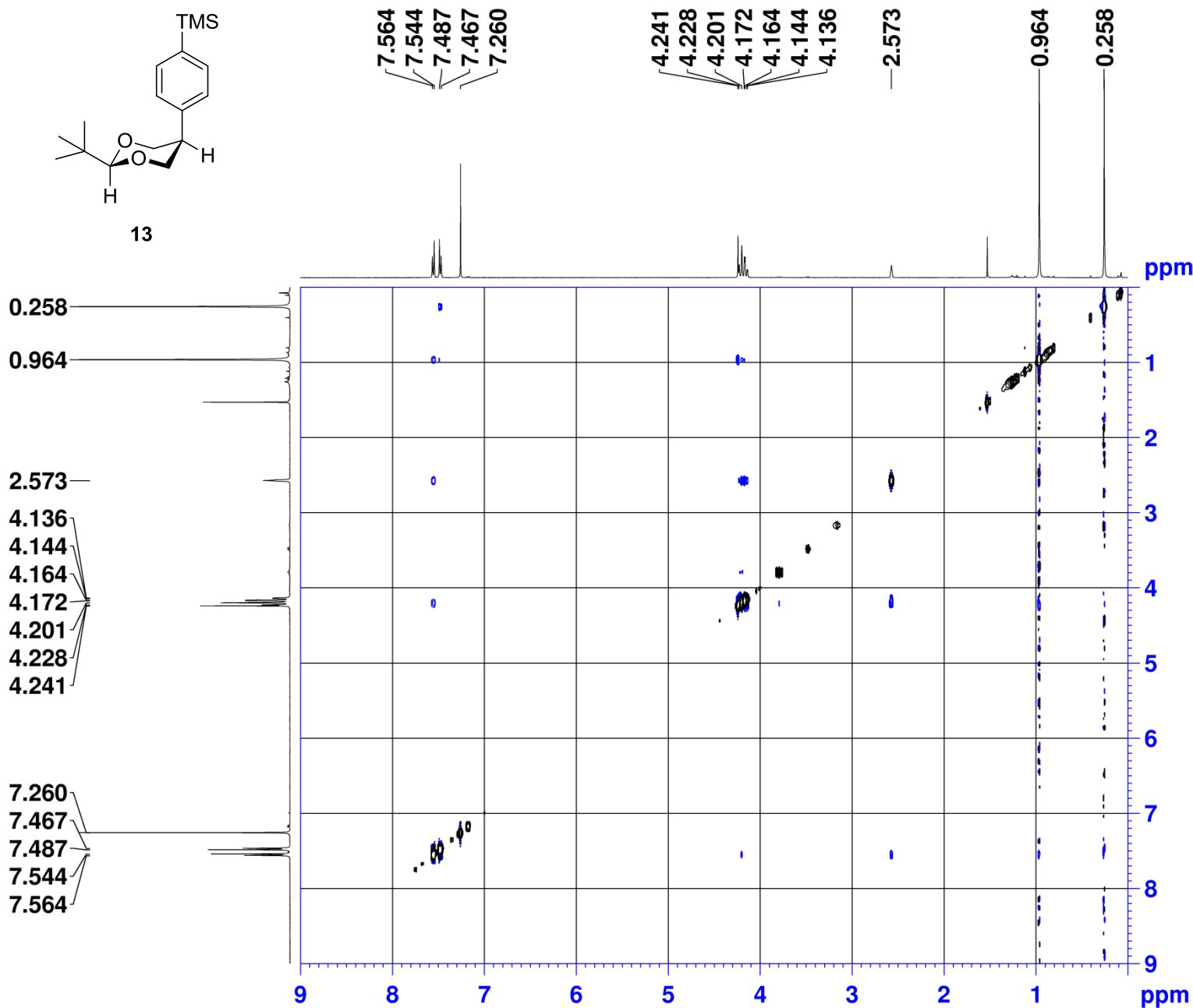
===== CHANNEL f1 =====
SF01 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

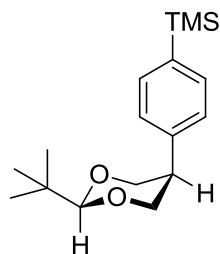
===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SF01 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

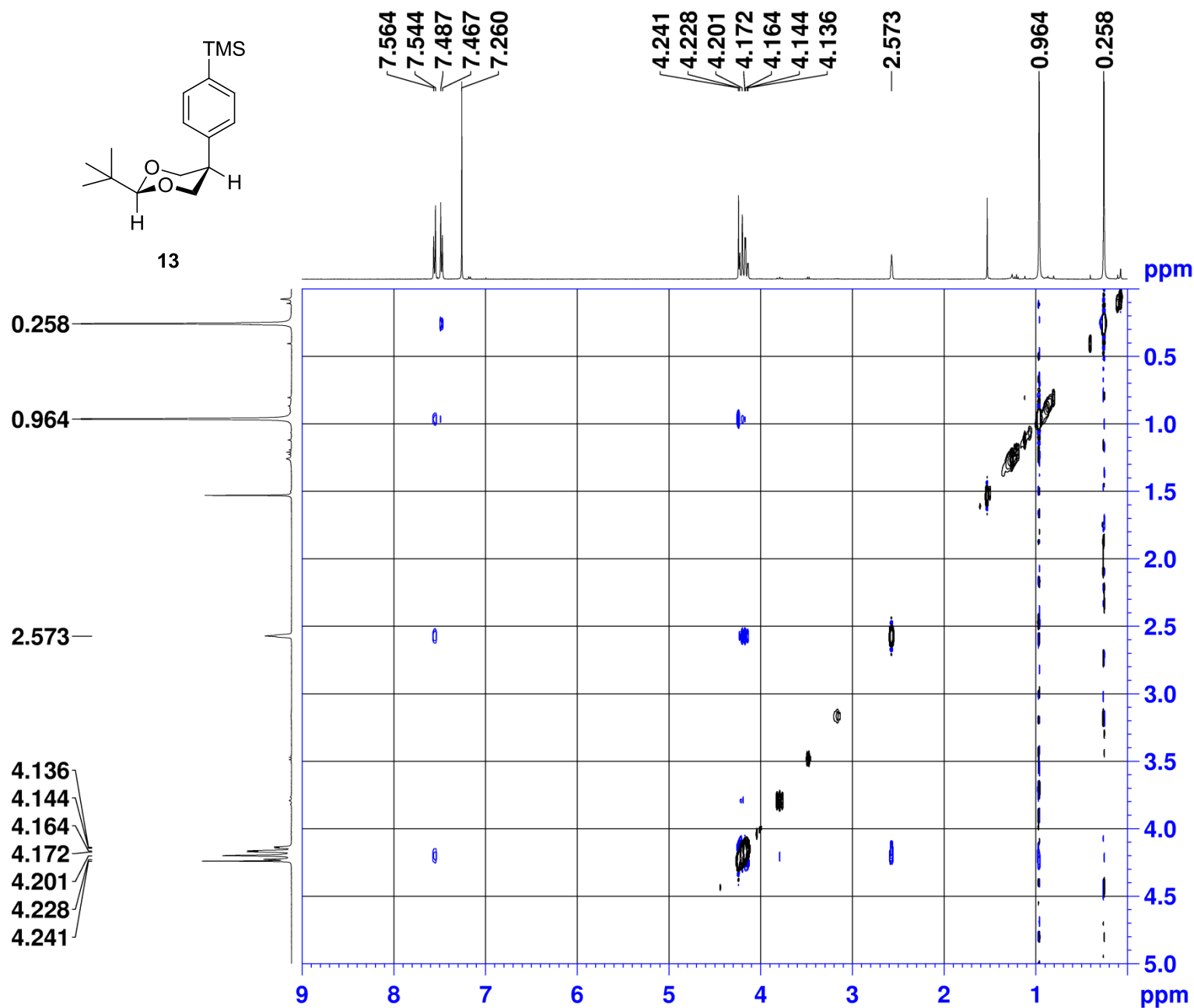
F2 - Processing parameters
SI 1024
SF 400.1440083 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440084 MHz
WDW
SSB 2
LB 0 Hz
GB 0





13



Current Data Parameters
NAME kl-2-203-HNOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20151008
Time 23.49
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphpp
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 203
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

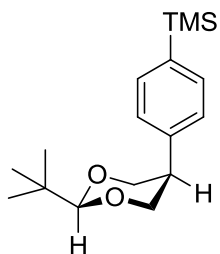
===== CHANNEL f1 =====
SF01 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

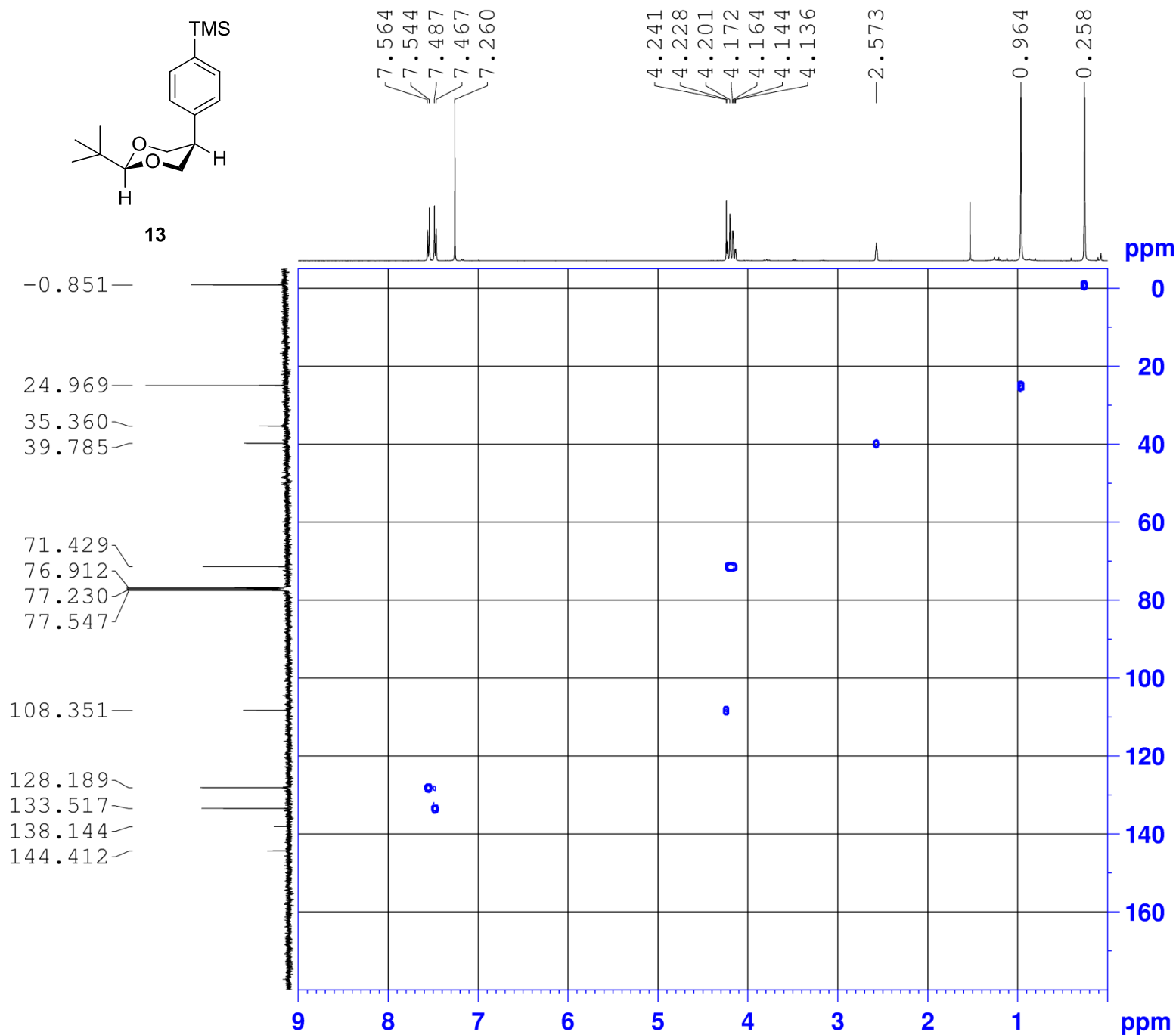
F1 - Acquisition parameters
TD 256
SF01 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440083 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440084 MHz
WDW
SSB 2
LB 0 Hz
GB 0



13



Current Data Parameters
NAME kl-2-203-HSQC
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20131008
Time 22.27
INSTRUM spect
PROBHD 5 mm PARBO BB/
PULPROG hsqcetdgp1sp2.3
TD 1024
SOLVENT CDCl₃
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNS12 145.000000
CNS17 -0.5000000
D0 0.00000300 sec
D1 1.00000000 sec
D4 0.00172414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.00360000 sec
D24 0.00089000 sec
IN0 0.0003010 sec

===== CHANNEL f1 =====
SFO1 400.1458807 MHz
NUC1 13
P1 15.25 usec
P2 30.50 usec
P28 1000.00 usec
PLW1 12.00000000 W

===== CHANNEL f2 =====
SFO2 100.6233320 MHz
NUC2 13C
CPDPRG2 2 bl_p5m4sp_4sp.2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1900.00 usec
P63 1500.00 usec
PLW0 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SFOAL3 0.500
SPOFFS3 0 Hz
SPW1 7.63940001 W
SPNAM[7] Crp60decp.4
SFOAL7 0.500
SPOFFS7 0 Hz
SPW7 7.63940001 W
SPNAM[14] Crp32,1.5,20.2
SFOAL14 0.500
SPOFFS14 0 Hz
SPW14 3.25950003 W
SPNAM[18] Crp60_kfilt.2
SFOAL18 0.500
SPOFFS18 0 Hz
SPW18 1.83050001 W
SPNAM[31] Crp32,1.5,20.2
SFOAL31 0.500
SPOFFS31 0 Hz
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPNAM[3] SMSQ10.100
GPNAM[4] SMSQ10.100
GP21 80.00 %
GP22 20.10 %
GP23 11.00 %
GP24 5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 128
SFO1 100.6233 MHz
FIDRES 129.775742 Hz
SW 165.084 ppm
FMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440979 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162571 MHz
WDW States
SSB 2
LB 0 Hz
GB 0



Current Data Parameters
NAME k1-2-203-equatorial H1
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150911
Time 22.34
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 36
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

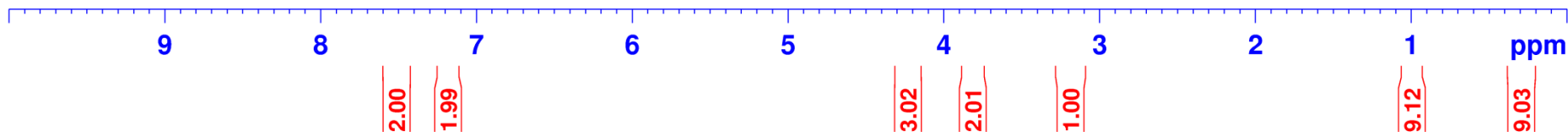
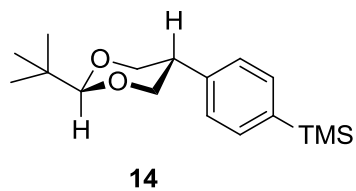
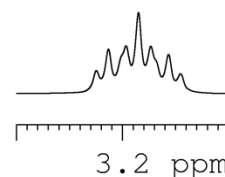
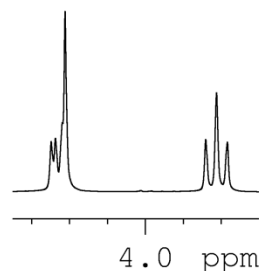
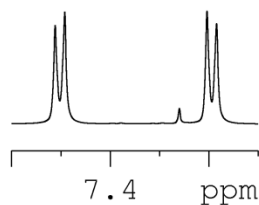
F2 - Processing parameters
SI 131072
SF 400.1440092 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00

7.51
7.49
7.26
7.20
7.18

4.25
4.24
4.22
4.21
3.84
3.81
3.78
3.22
3.21
3.20
3.18
3.17
3.16
3.14

0.98

0.28





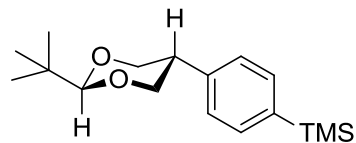
Current Data Parameters
NAME kl-2-203-equatorial c13
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150911
Time 22.43
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 97
DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
AQ 0.8652204 sec
RG 203
DW 19.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

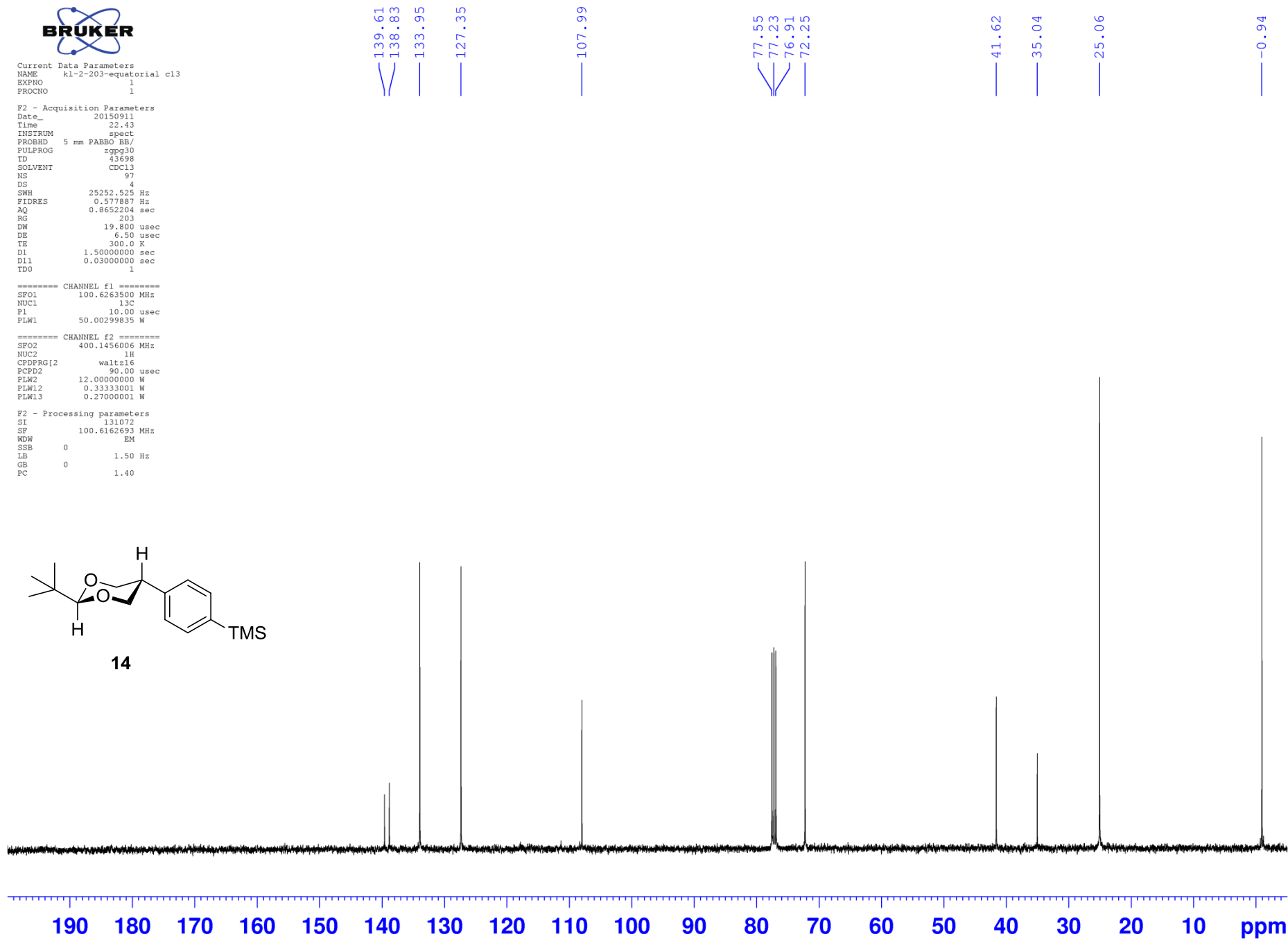
===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

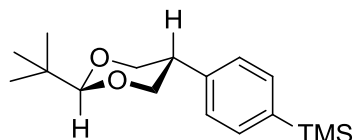
===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162693 MHz
WDW EM
SSB 0
LB 1.50 Hz
GB 0
PC 1.40

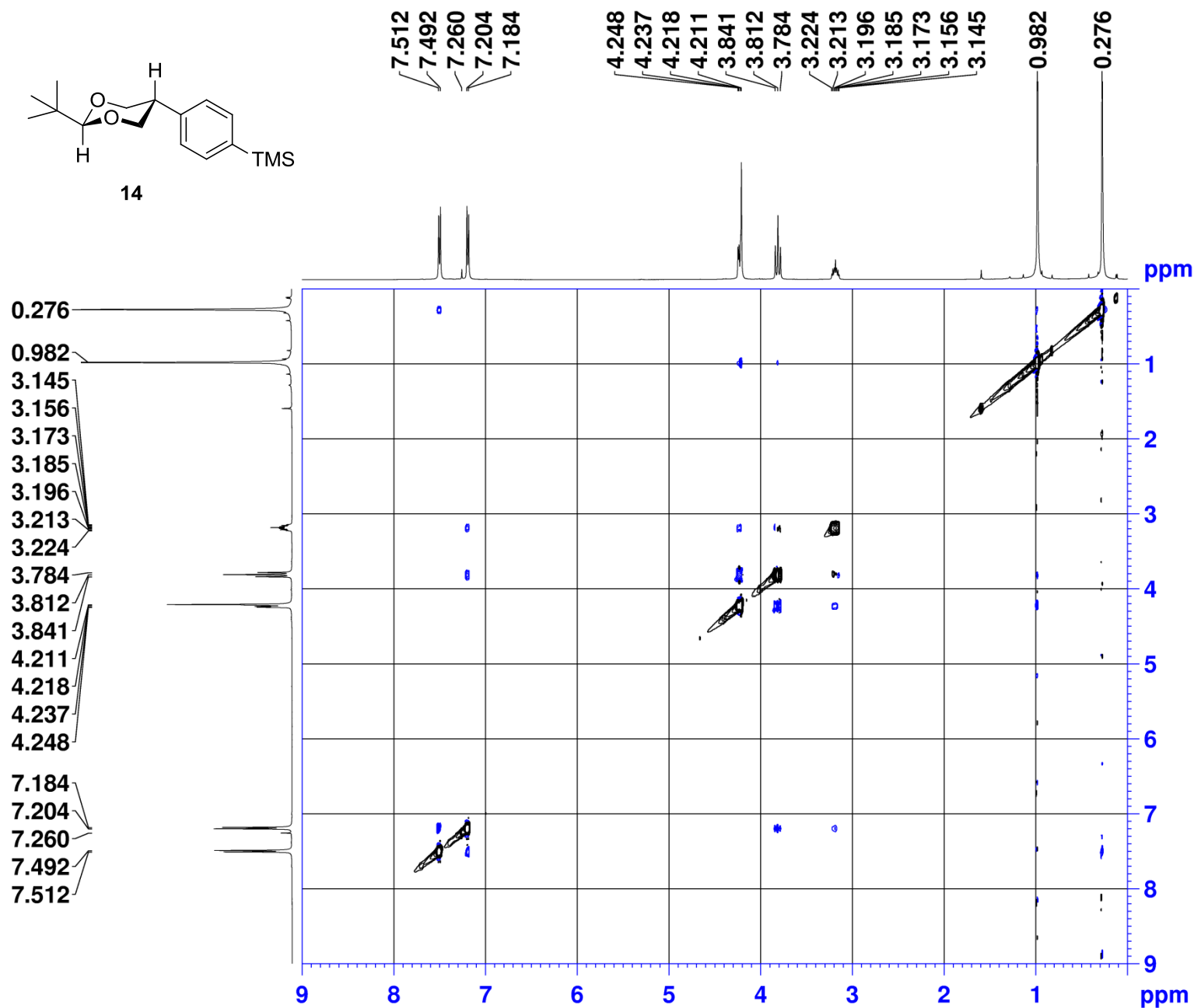


14





14



Current Data Parameters
NAME kl-2-203-HNOESY-equatorial
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150911
Time 23.09
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpph
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 80.6
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

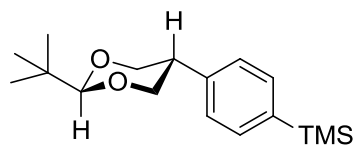
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

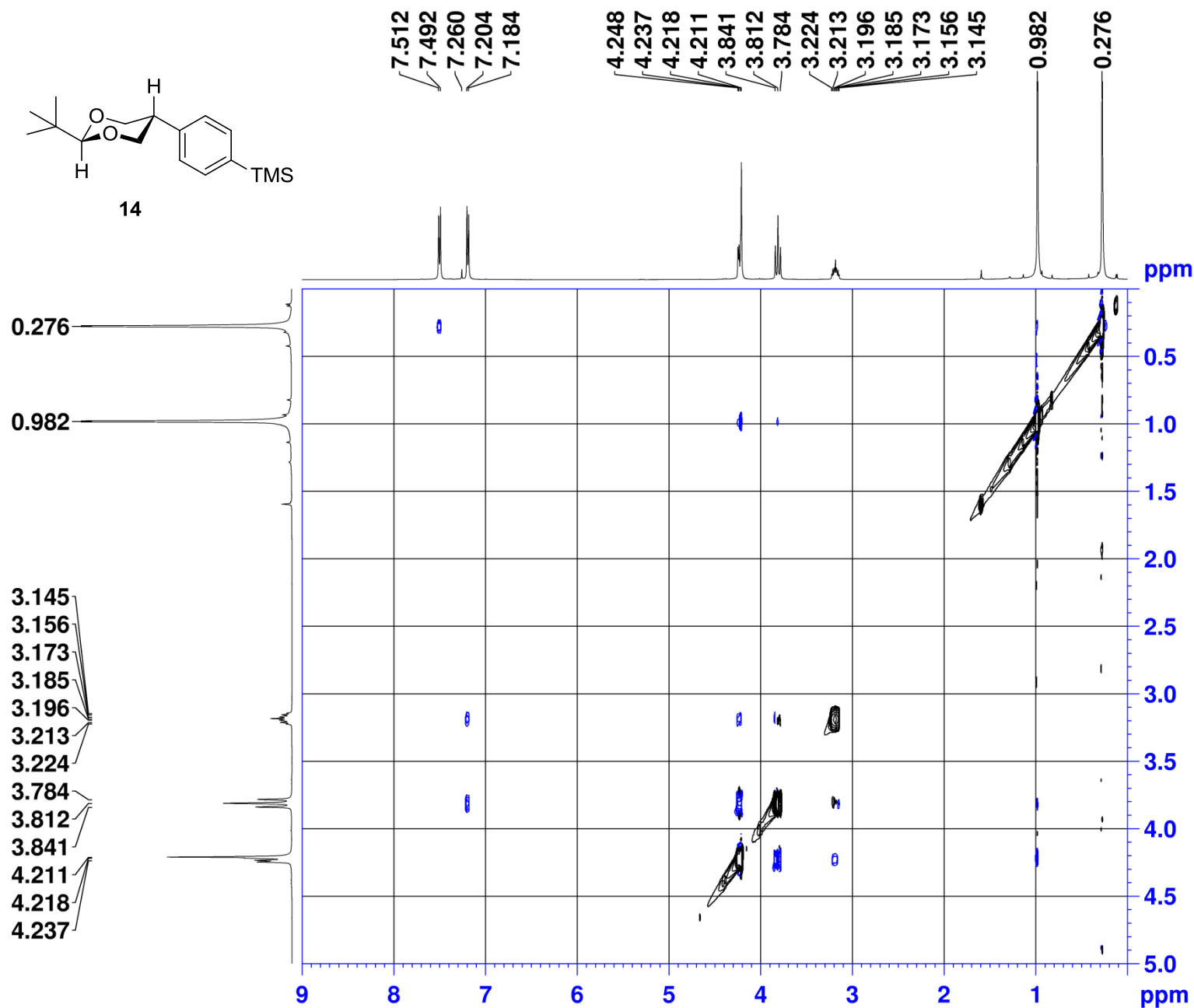
F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440081 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440081 MHz
WDW
SSB 2
LB 0 Hz
GB 0



14



Current Data Parameters
NAME kl-2-203-HNOESY-equatorial
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150911
Time 23.09
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphph
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 80.6
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

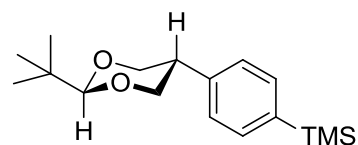
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GP21 40.00 %
P16 1000.00 usec

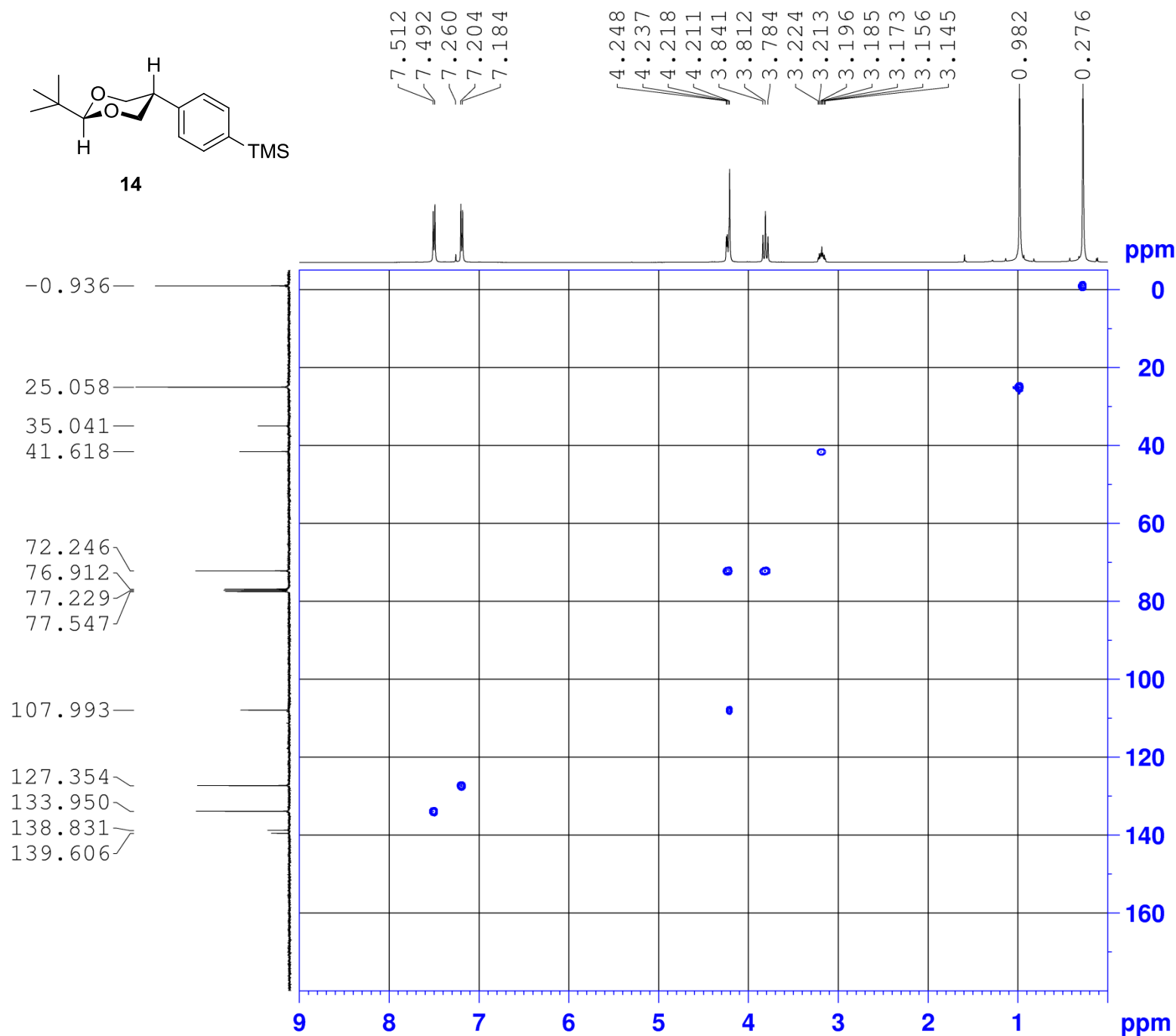
F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440081 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440081 MHz
WDW
SSB 2
LB 0 Hz
GB 0



14



Current Data Parameters
NAME kl-2-203-RSQC-equatorial
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150911
Time 22.46
INSTRUM spect
PROBHD 5 mm PARBO BB/
PULPROG hsqcetdetsps2.3
TD 1024
SOLVENT CDCl3
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNST2 145.000000
CNST17 -0.500000
D0 0.00000300 sec
D1 1.00000000 sec
D4 0.00172414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.00360000 sec
D24 0.00089000 sec
IN0 0.0003010 sec

===== CHANNEL f1 =====
SFO1 400.1458971 MHz
NUC1 13C
P1 15.25 usec
P2 30.50 usec
P28 1000.00 usec
PLW1 12.00000000 W

===== CHANNEL f2 =====
SFO2 100.6233320 MHz
NUC2 13C
CPDPRG2 bl_p5m4p_4sp_2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1900.00 usec
P63 1500.00 usec
PLW0 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SFOAL3 0.500
SPOFFS3 0 Hz
SPW3 7.63940001 W
SPNAM[7] Crp60decap_4
SFOAL7 0.500
SPOFFS7 0 Hz
SPW7 7.63940001 W
SPNAM[14] Crp32,1.5,20.2
SFOAL14 0.500
SPOFFS14 0 Hz
SPW14 3.25950003 W
SPNAM[18] Crp60_kfilt_2
SFOAL18 0.500
SPOFFS18 0 Hz
SPW18 1.83050001 W
SPNAM[31] Crp32,1.5,20.2
SFOAL31 0.500
SPOFFS31 0 Hz
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPNAM[3] SMSQ10.100
GPNAM[4] SMSQ10.100
GP21 80.00 %
GP22 20.10 %
GP23 11.00 %
GP24 5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 128
SFO1 100.6233 MHz
FIDRES 129.775742 Hz
SW 165.084 ppm
FMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440070 MHz
WDW QSI
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162600 MHz
WDW States
SSB 2
LB 0 Hz
GB 0



Current Data Parameters
NAME kl-2-174-middle spot
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150624
Time 23.01
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 57
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440097 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00

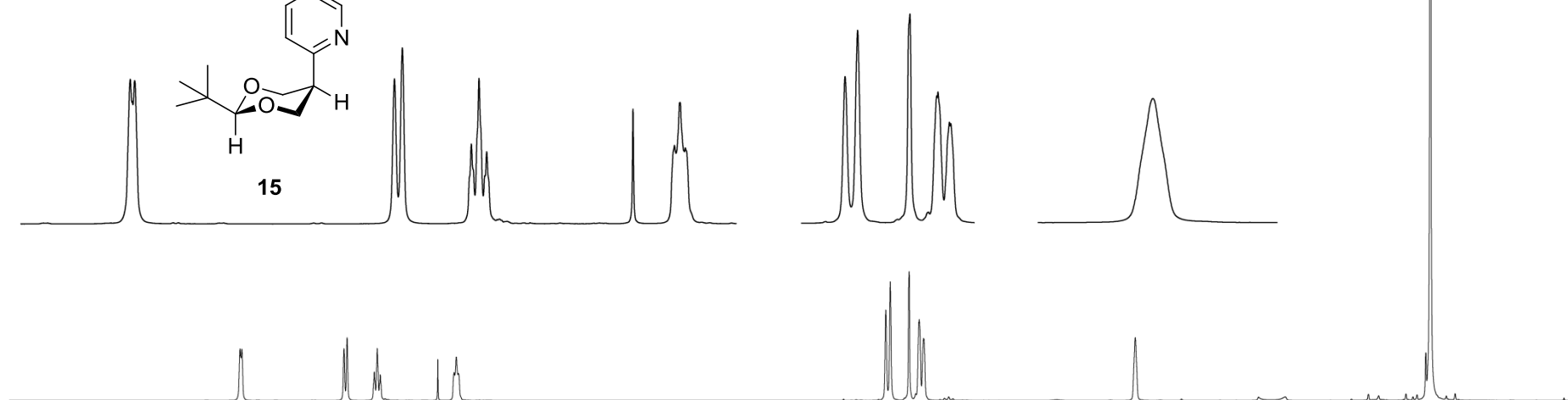
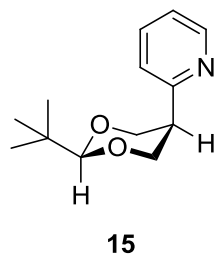
8.52
8.51

7.86
7.84
7.67
7.65
7.63
7.26
7.16
7.14
7.13

4.40
4.37
4.25
4.19
4.18
4.16
4.15

2.80

0.92



9

8

7

6

5

4

3

2

1

ppm

1.00

1.01

1.04

1.06

2.10

1.08

2.17

1.03

9.22



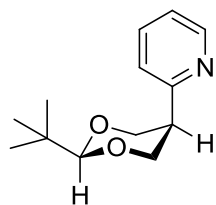
Current Data Parameters
NAME kl-2-174-middle spot-cl3
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150624
Time 23.08
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 77
DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
AQ 0.8652204 sec
RG 203
DW 19.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

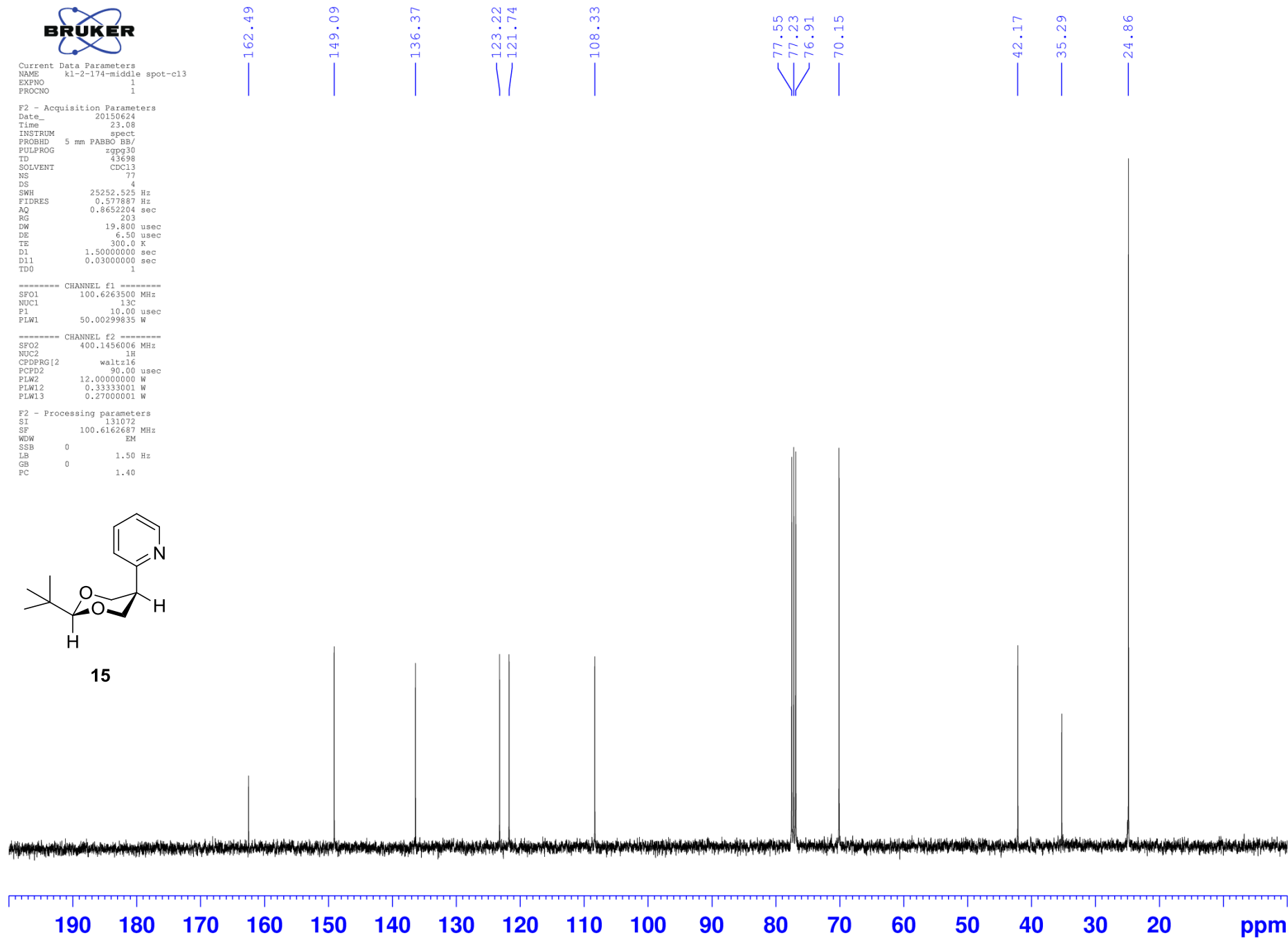
===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

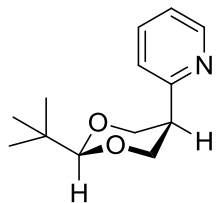
===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162687 MHz
WDW EM
SSB 0
LB 1.50 Hz
GB 0
PC 1.40



15





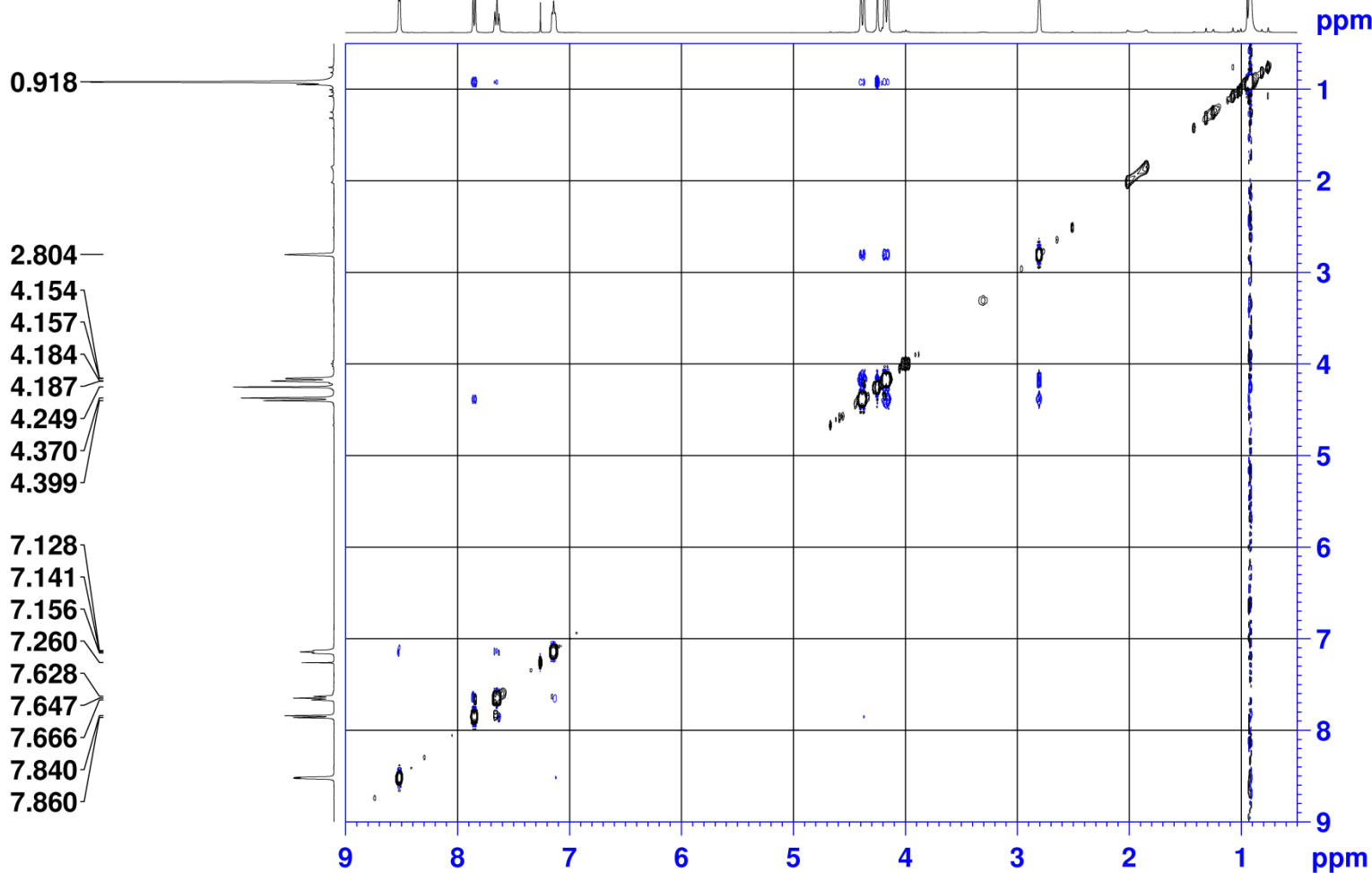
15

8.513
7.860
7.840
7.666
7.647
7.628
7.260
7.156
7.141
7.128

4.399
4.370
4.249
4.187
4.184
4.157
4.154

2.804

0.918



Current Data Parameters
NAME kl-2-174-middle spot-NOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150624
Time 23.12
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpph
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 114
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00020000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

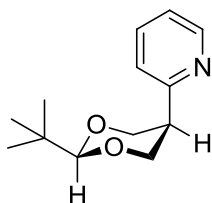
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GP21 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440084 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440084 MHz
WDW
SSB 2
LB 0 Hz
GB 0



15

8.524
8.513

7.860
7.840
7.666
7.647
7.628

7.260
7.156
7.141
7.128



Current Data Parameters
NAME k1-2-174-middle spot-NOESY
EXPNO 1
PROCNO 1

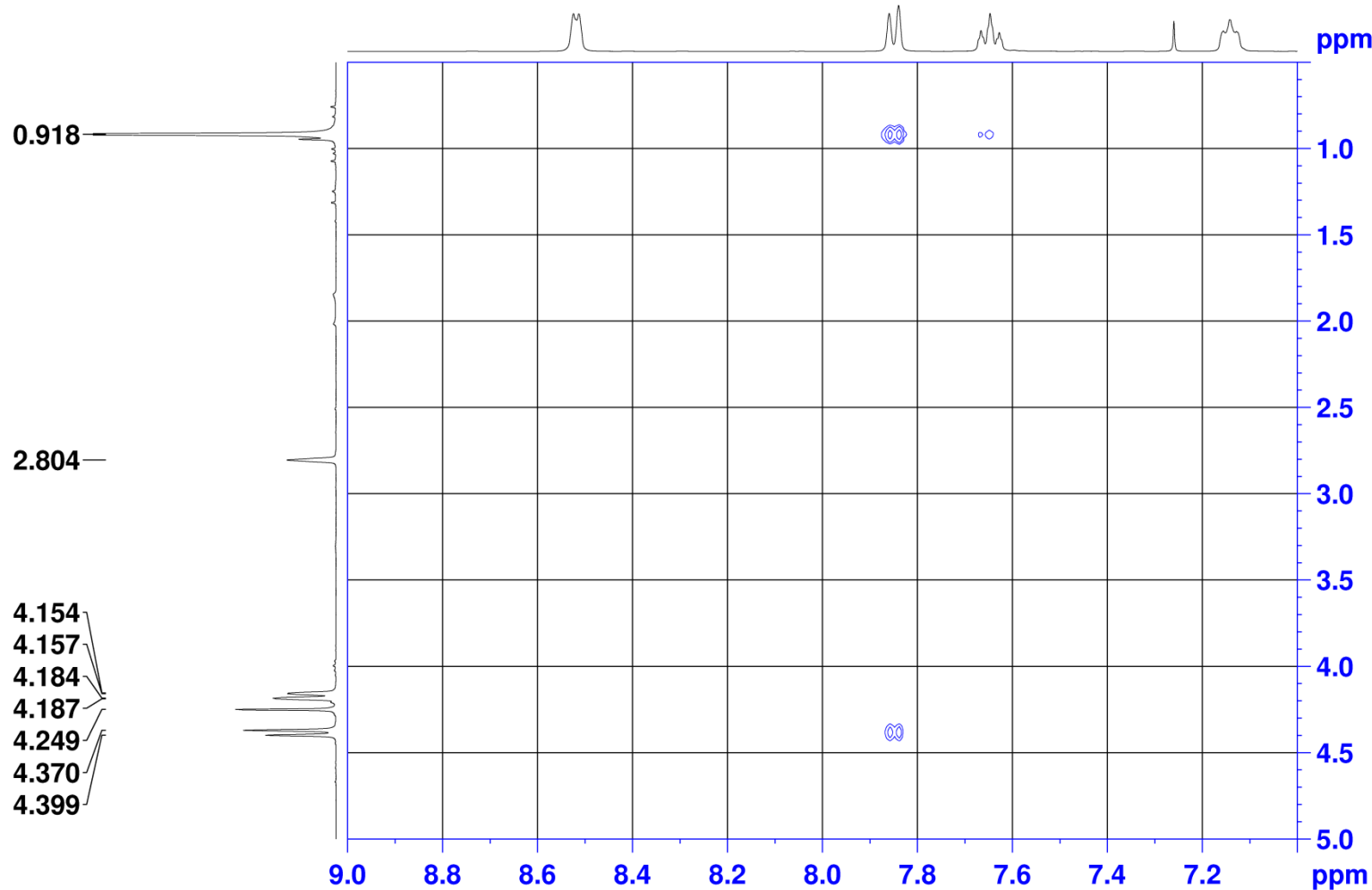
F2 - Acquisition Parameters
Date_ 20150624
Time 23.12
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpph
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 114
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00020000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

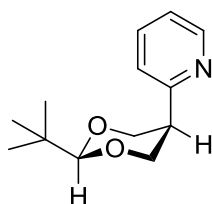
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W
===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GP21 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440084 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440084 MHz
WDW
SSB 2
LB 0 Hz
GB 0





15

8.524
8.513

7.860
7.840
7.666
7.647
7.628

7.260
7.156
7.141
7.128



Current Data Parameters
NAME kl-2-174-middle spot-NOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150624
Time 23.12
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpph
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 114
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00020000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GP21 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

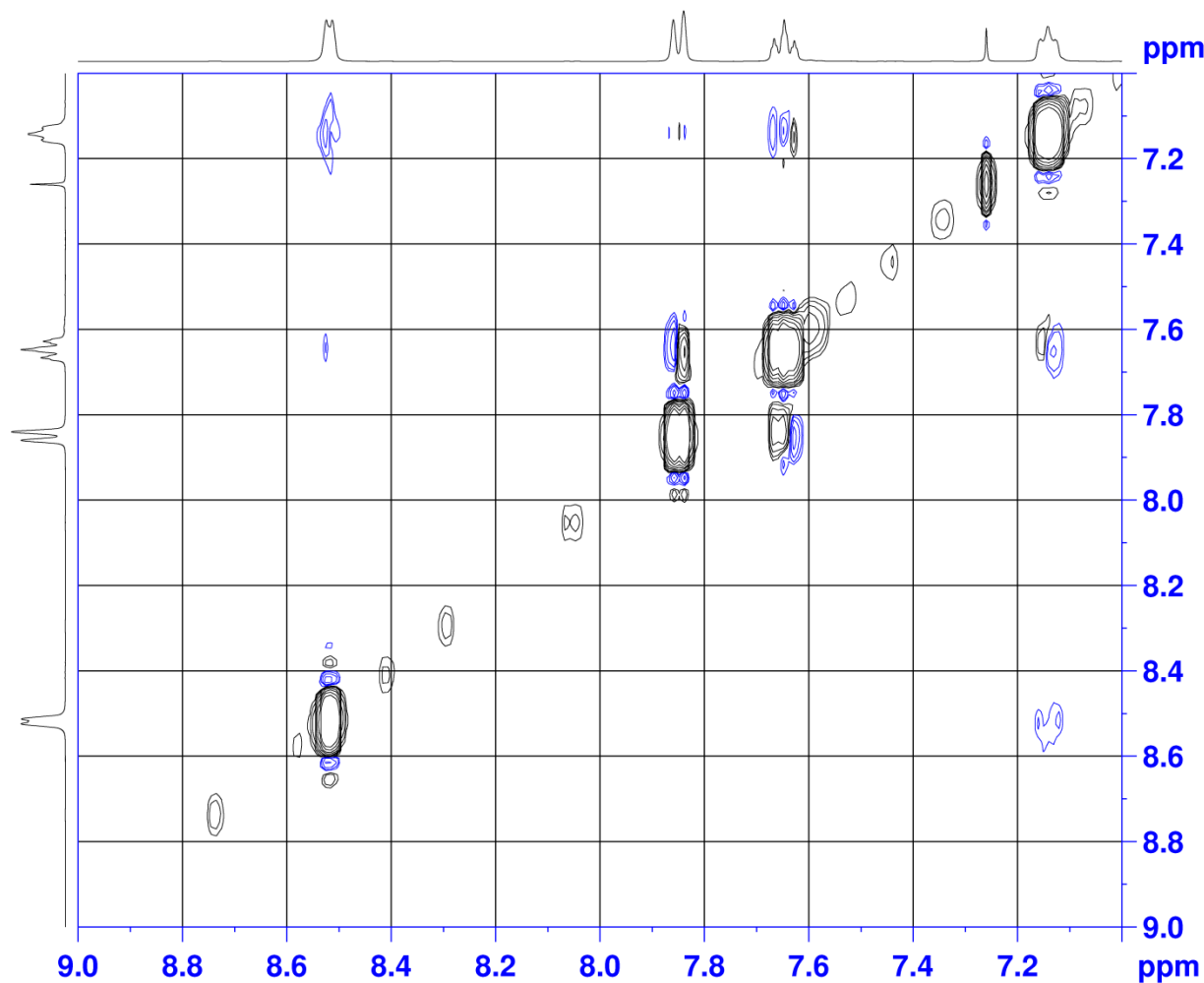
F2 - Processing parameters
SI 1024
SF 400.1440084 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

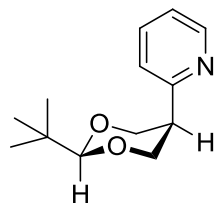
F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440084 MHz
WDW
SSB 2
LB 0 Hz
GB 0

7.128
7.141
7.156
7.260

7.628
7.647
7.666
7.840
7.860

8.513
8.524





15

4.399
4.370
4.249
4.187
4.184
4.157
4.154

2.804

0.918



Current Data Parameters
NAME kl-2-174-middle spot-NOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150624
Time 23.12
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpph
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 114
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00020000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GP21 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440084 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440084 MHz
WDW
SSB 2
LB 0 Hz
GB 0

0.918

2.804

4.154
4.157
4.184
4.187
4.249
4.370
4.399

5.0

4.5

4.0

3.5

3.0

2.5

2.0

1.5

1.0

0.5

0.0

0.5

1.0

1.5

2.0

2.5

3.0

3.5

4.0

4.5

5.0

ppm

1.0

1.5

2.0

2.5

3.0

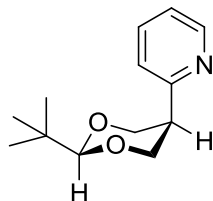
3.5

4.0

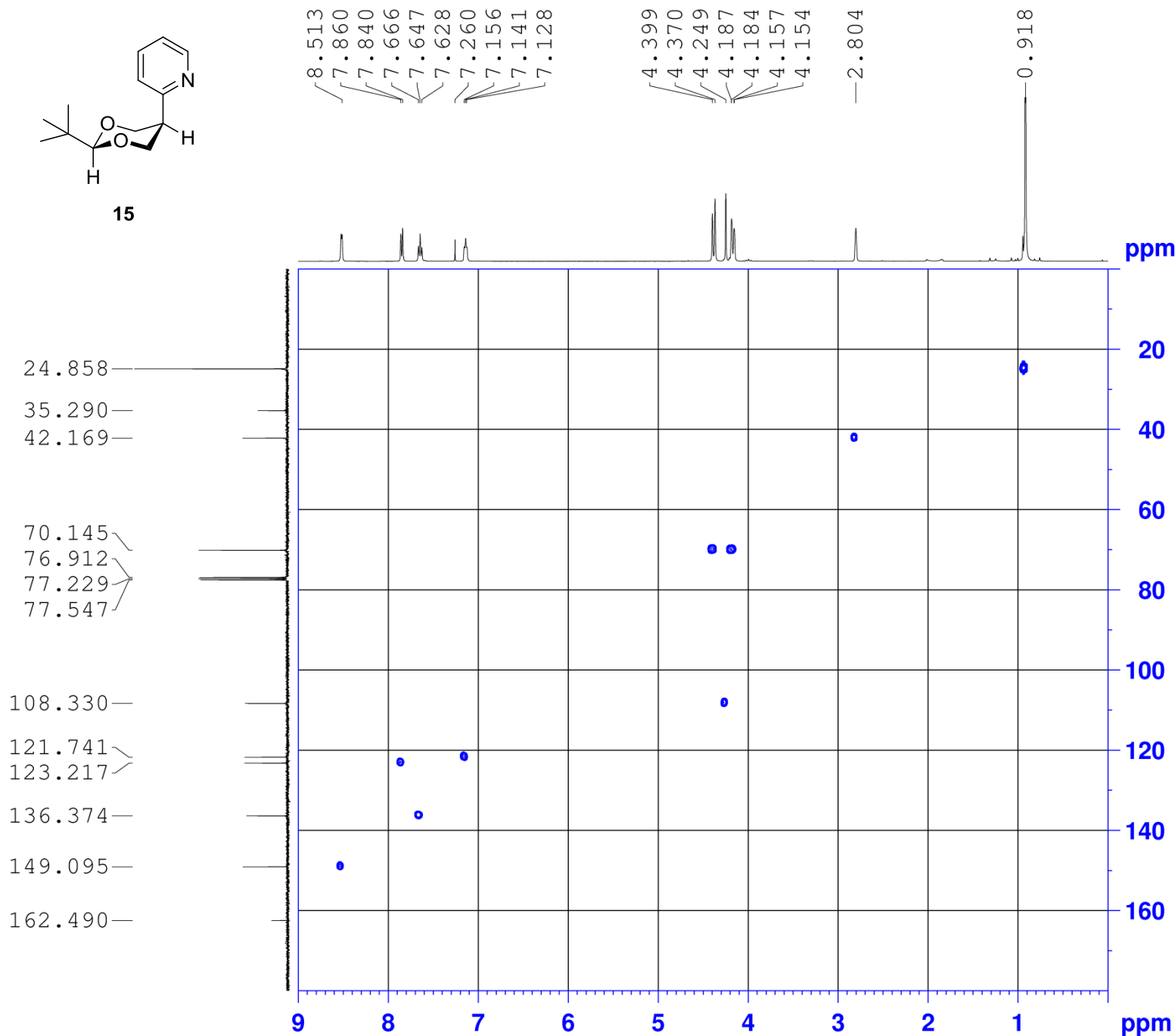
4.5

5.0

ppm



15



Current Data Parameters
NAME kl-2-174-middle spot-HSQC
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150625
Time 0.08
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG hsqcetdetsps2.3
TD 1024
SOLVENT CDCl3
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNS2 145.000000
CNS17 -0.5000000
D0 0.00000300 sec
D1 1.50000000 sec
D4 0.00172414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.00360000 sec
D24 0.00089000 sec
INO 0.00003010 sec

===== CHANNEL f1 =====
SFO1 400.1458807 MHz
NUC1 1H
P1 15.25 usec
P2 30.50 usec
P28 1000.00 usec
PLW1 12.00000000 W

===== CHANNEL f2 =====
SFO2 100.6233320 MHz
NUC2 13C
CPDPRG2 bi_p5m4sp_4sp.2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1900.00 usec
P63 1500.00 usec
PLW0 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SFOAL3 0.500
SPOFFS3 0 Hz
SPW3 7.63940001 W
SPNAM[7] Crp60comp.4
SFOAL7 0.500
SPOFFS7 0 Hz
SPW7 7.63940001 W
SPNAM[14] Crp32,1.5,20.2
SFOAL14 0.500
SPOFFS14 0 Hz
SPW14 3.25950003 W
SPNAM[18] Crp60_kfilt.2
SFOAL18 0.500
SPOFFS18 0 Hz
SPW18 1.83050001 W
SPNAM[31] Crp32,1.5,20.2
SFOAL31 0.500
SPOFFS31 0 Hz
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPNAM[3] SMSQ10.100
GPNAM[4] SMSQ10.100
GPZ1 80.00 %
GPZ2 20.10 %
GPZ3 11.00 %
GPZ4 -5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 128
SFO1 100.6233 MHz
FIDRES 129.775742 Hz
SW 165.084 ppm
FnMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162890 MHz
WDW
SSB 2
LB 0 Hz
GB 0



8.53
8.52

7.62
7.61
7.60
7.59
7.58
7.57
7.26
7.15
7.13
7.11

4.28
4.26
4.25
4.23
4.20
4.02
3.99
3.96
3.34
3.33
3.31
3.30
3.29
3.27
3.26

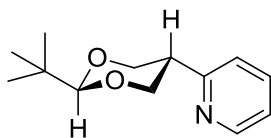
0.94

Current Data Parameters
NAME kl-2-174-top spot1
EXPNO 1
PROCNO 1

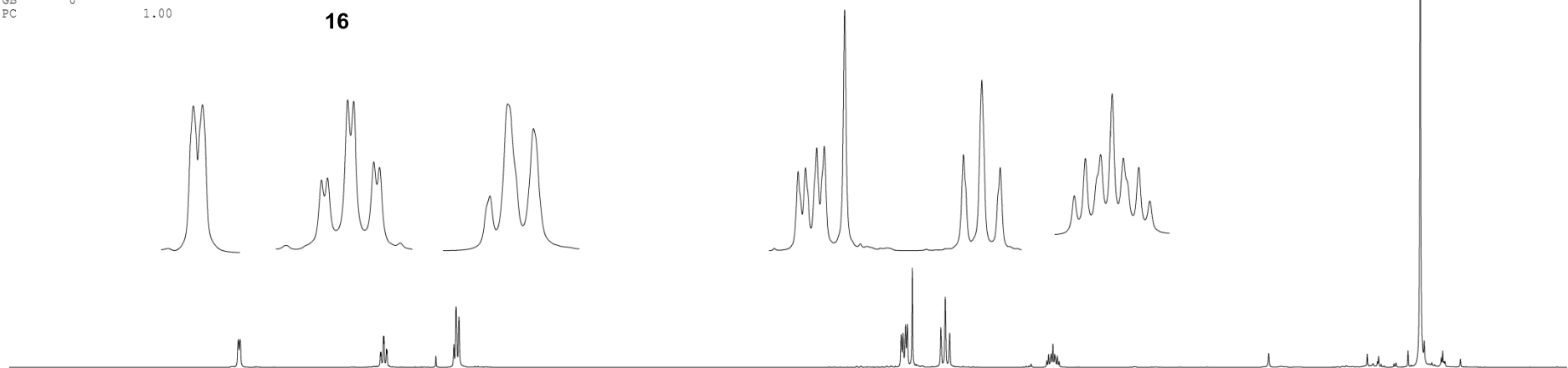
F2 - Acquisition Parameters
Date_ 20150625
Time 1.49
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 40.3
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SF01 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440097 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00



16



9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 ppm

0.94

1.02

2.03

2.05

1.05

2.14

1.00

9.06



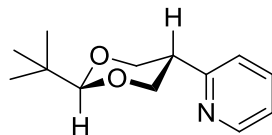
Current Data Parameters
NAME kl-2-174-top spot-cl3
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150625
Time 1.56
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 43698
SOLVENT CDCl3
NS 77
DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
AQ 0.8652204 sec
RG 203
DW 19.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

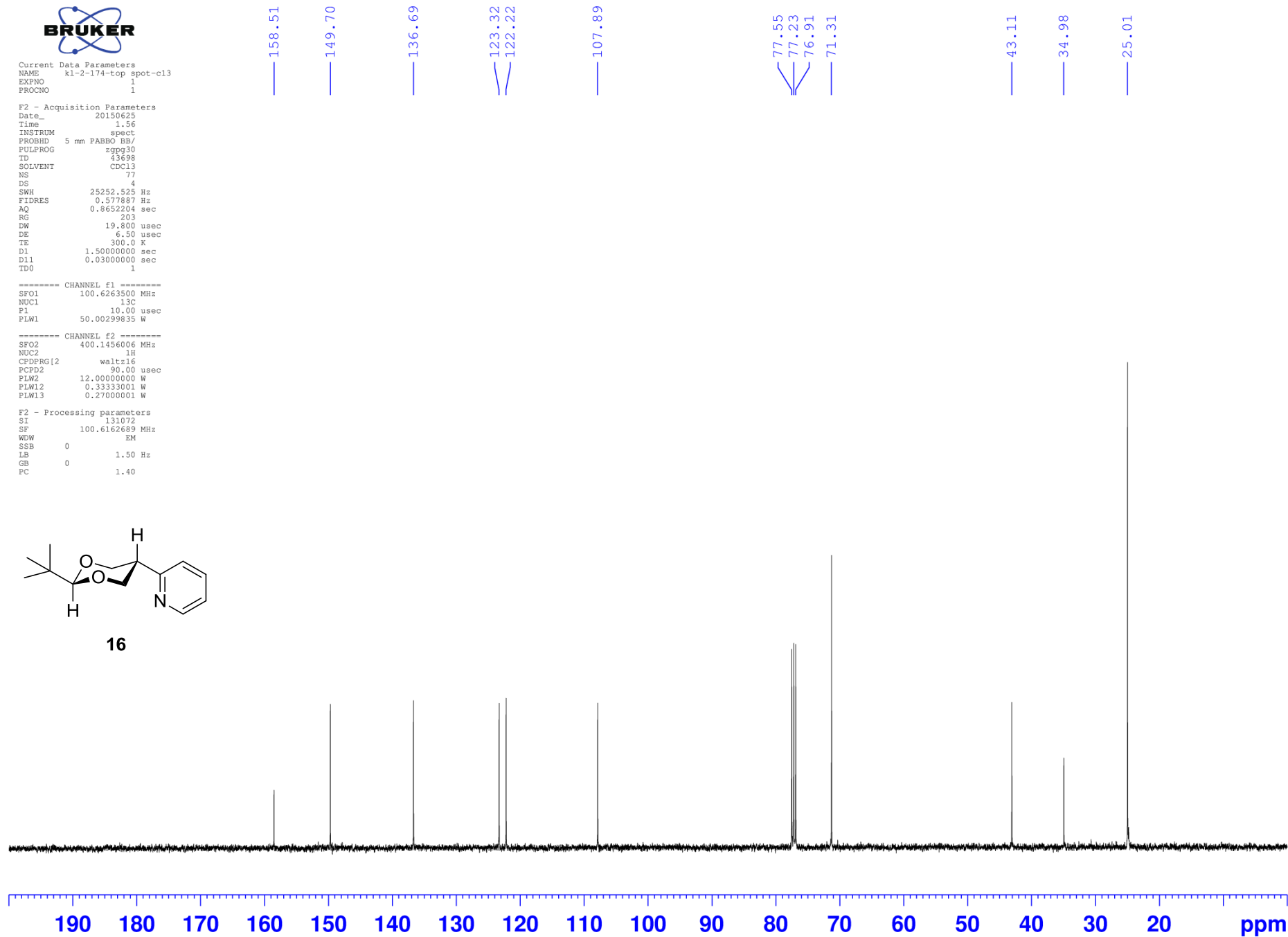
===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162689 MHz
WDW EM
SSB 0
LB 1.50 Hz
GB 0
PC 1.40



16





Current Data Parameters
NAME kl-2-174-top spot-NOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150625
Time 2.16
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphpp
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 80.6
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00020000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

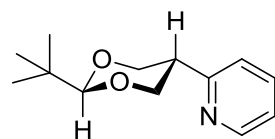
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GP21 40.00 %
P16 1000.00 usec

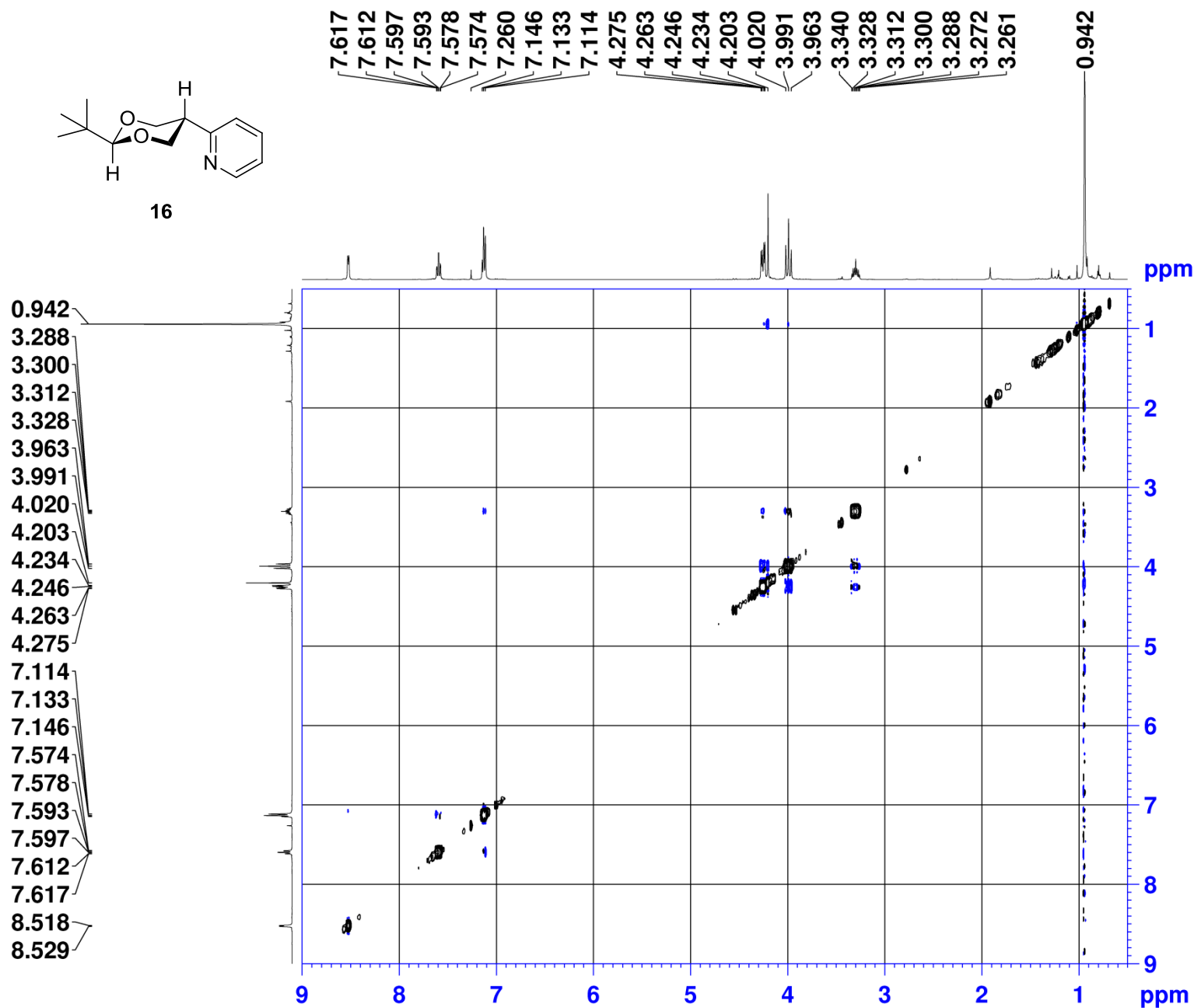
F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

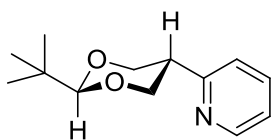
F2 - Processing parameters
SI 1024
SF 400.1440081 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440082 MHz
WDW
SSB 2
LB 0 Hz
GB 0



16





16

8.529
8.518

7.617
7.612
7.597
7.593
7.578
7.574

7.260
7.146
7.133
7.114



Current Data Parameters
NAME k1-2-174-top spot-NOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150625
Time 2.16
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphpp
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 80.6
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00020000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

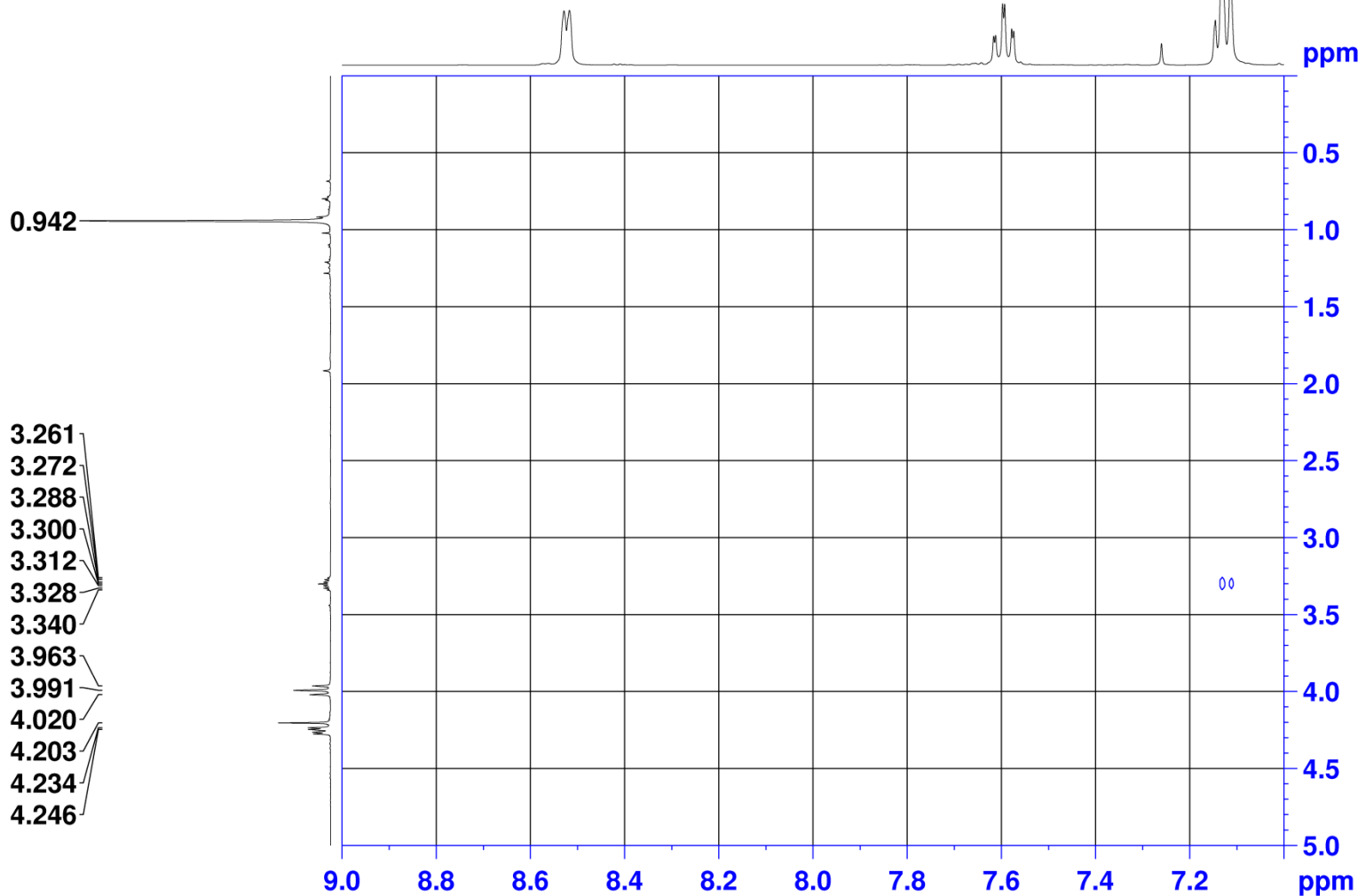
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

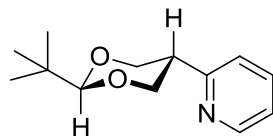
===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GP21 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440081 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440082 MHz
WDW
SSB 2
LB 0 Hz
GB 0





16

8.529
8.518

7.617
7.612
7.597
7.593
7.578
7.574

7.260
7.146
7.133
7.114



Current Data Parameters
NAME kl-2-174-top spot-NOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150625
Time 2.16
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphpp
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 80.6
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00020000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W
===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GP21 40.00 %
P16 1000.00 usec

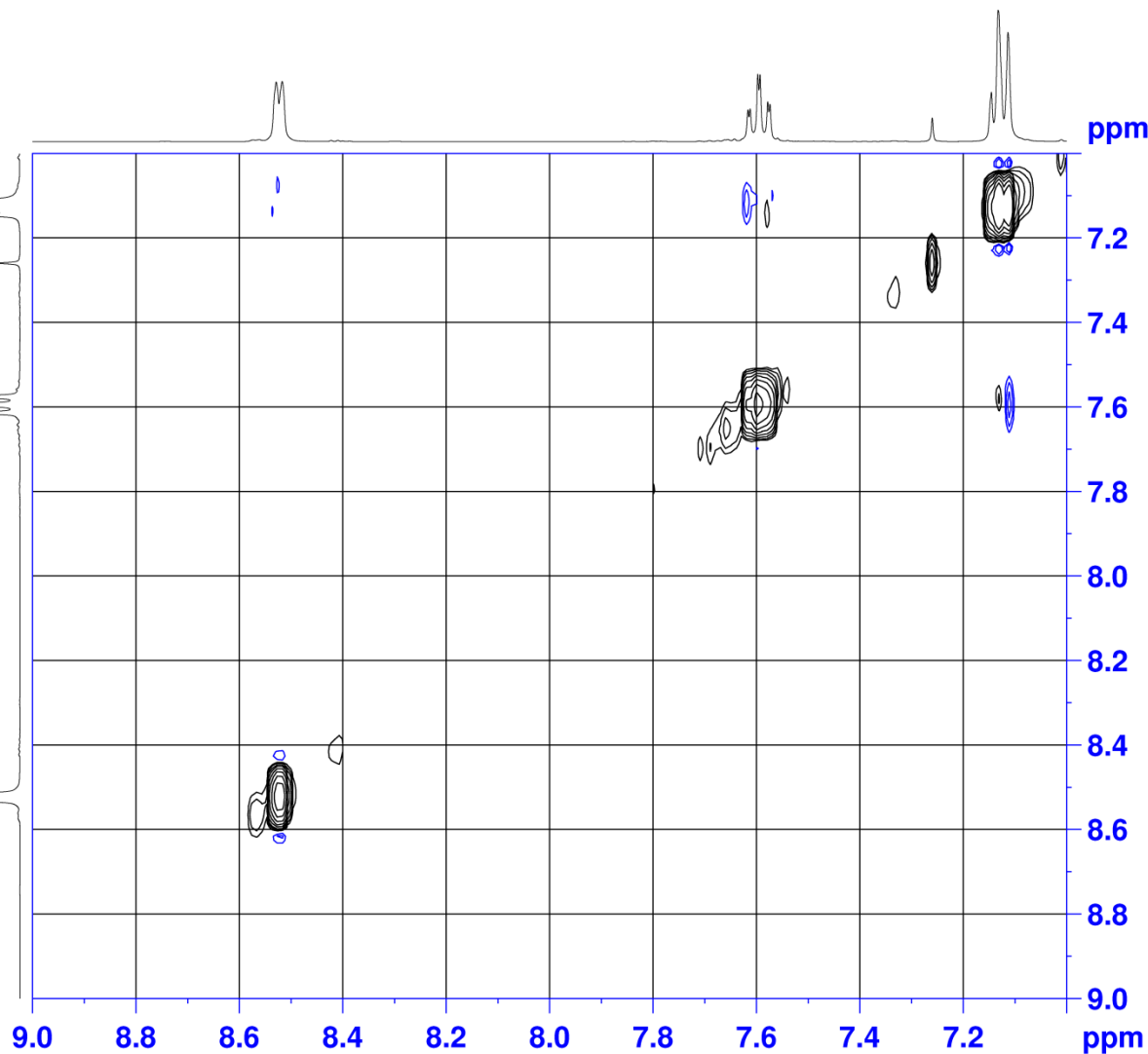
F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

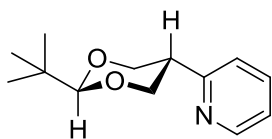
F2 - Processing parameters
SI 1024
SF 400.1440081 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440082 MHz
WDW
SSB 2
LB 0 Hz
GB 0

7.133
7.146
7.260
7.574
7.578
7.593
7.597
7.612
7.617

8.518
8.529





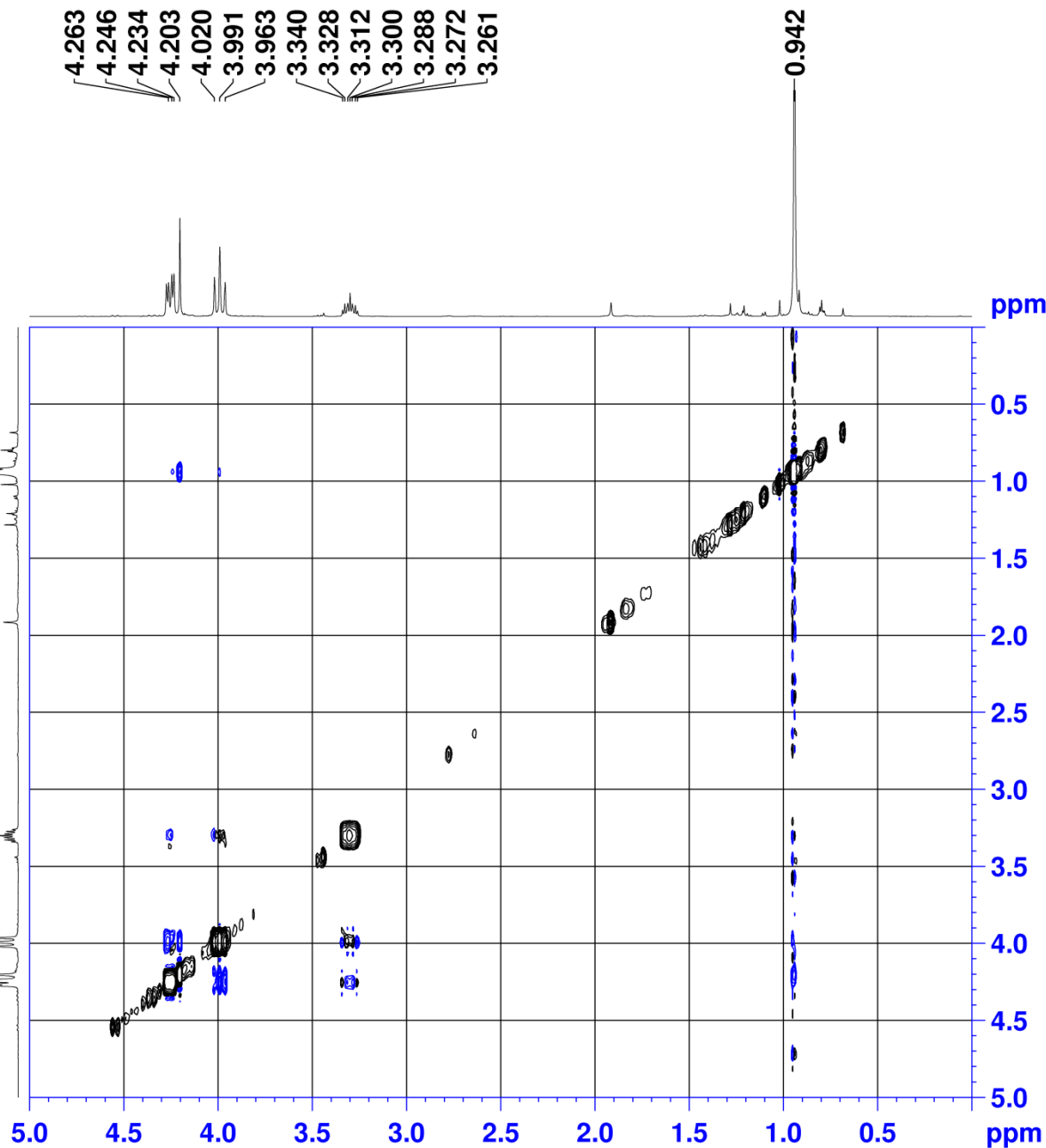
16

4.263
4.246
4.234
4.203
4.020
3.991
3.963
3.340
3.328
3.312
3.300
3.288
3.272
3.261

0.942

0.942

3.261
3.272
3.288
3.300
3.312
3.328
3.340
3.963
3.991
4.020
4.203
4.234
4.246



Current Data Parameters
NAME kl-2-174-top spot-NOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150625
Time 2.16
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpphph
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 80.6
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00020000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

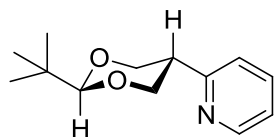
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GP21 40.00 %
P16 1000.00 usec

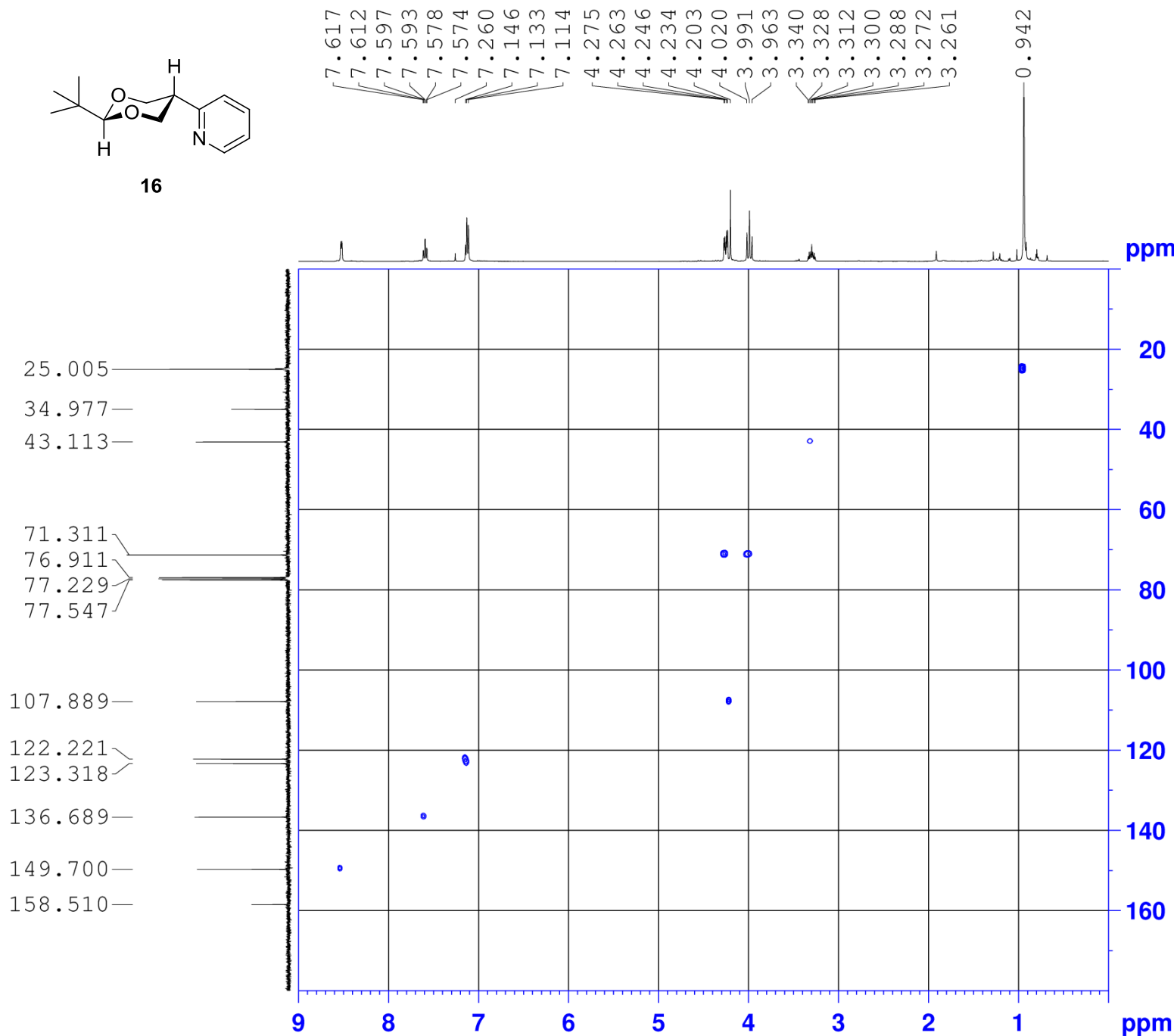
F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440081 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440082 MHz
WDW
SSB 2
LB 0 Hz
GB 0



16



Current Data Parameters
NAME kl-2-174-top spot-HSQC
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150625
Time 1.59
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG hsqcetdetspsisp2.3
TD 1024
SOLVENT CDCl3
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNS2 145.000000
CNS17 -0.5000000
D0 0.00000300 sec
D1 1.50000000 sec
D4 0.00172414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.00360000 sec
D24 0.00089000 sec
INO 0.00003010 sec

===== CHANNEL f1 =====
SFO1 400.145807 MHz
NUC1 1H
P1 15.25 usec
P2 30.50 usec
P28 1000.00 usec
PLW1 12.00000000 W

===== CHANNEL f2 =====
SFO2 100.623320 MHz
NUC2 13C
CPDPRG2 bl_p5m4sp_4sp.2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1900.00 usec
P63 1500.00 usec
PLW0 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SFO13 0.500
SPOFFS3 0 Hz
SPW3 SPNAM[7] 7.63940001 W
SFOAL7 Crp60comp.4
SPOAL7 0.500
SPOFFS7 0 Hz
SPW7 7.63940001 W
SPNAM[14] Crp32,1.5,20.2
SFOAL14 0.500
SPOFFS14 0 Hz
SPW14 3.25950003 W
SPNAM[18] Crp60_kfilt.2
SFOAL18 0.500
SPOFFS18 0 Hz
SPW18 1.83050001 W
SPNAM[31] Crp32,1.5,20.2
SFOAL31 0.500
SPOFFS31 0 Hz
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPNAM[3] SMSQ10.100
GPNAM[4] SMSQ10.100
GPZ1 80.00 %
GPZ2 20.10 %
GPZ3 11.00 %
GPZ4 5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 128
SFO1 100.6233 MHz
FIDRES 129.775742 Hz
SW 165.084 ppm
FnMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162890 MHz
WDW States
SSB 2
LB 0 Hz
GB 0

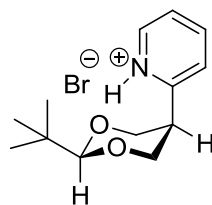


Current Data Parameters
NAME k1-196-1H
EXPNO 1
PROCNO 1

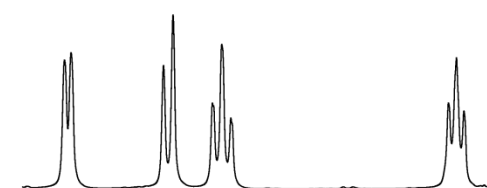
F2 - Acquisition Parameters
Date_ 20150826
Time 21.07
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 71.8
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
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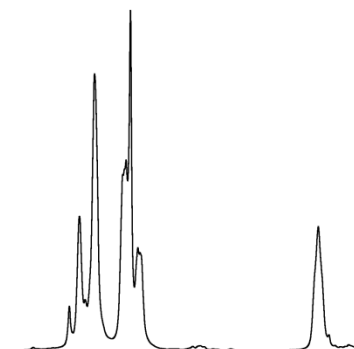
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17



4.39
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4.36
4.34
4.28
4.28
4.27
4.25
4.25
3.89



0.91



8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 ppm

1.00
1.01
1.08
1.03

630

5.58
1.00

9.24



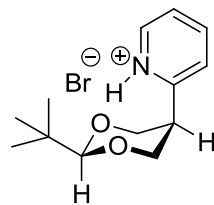
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PROCNO 1

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DS 4
SWH 25252.525 Hz
FIDRES 0.577887 Hz
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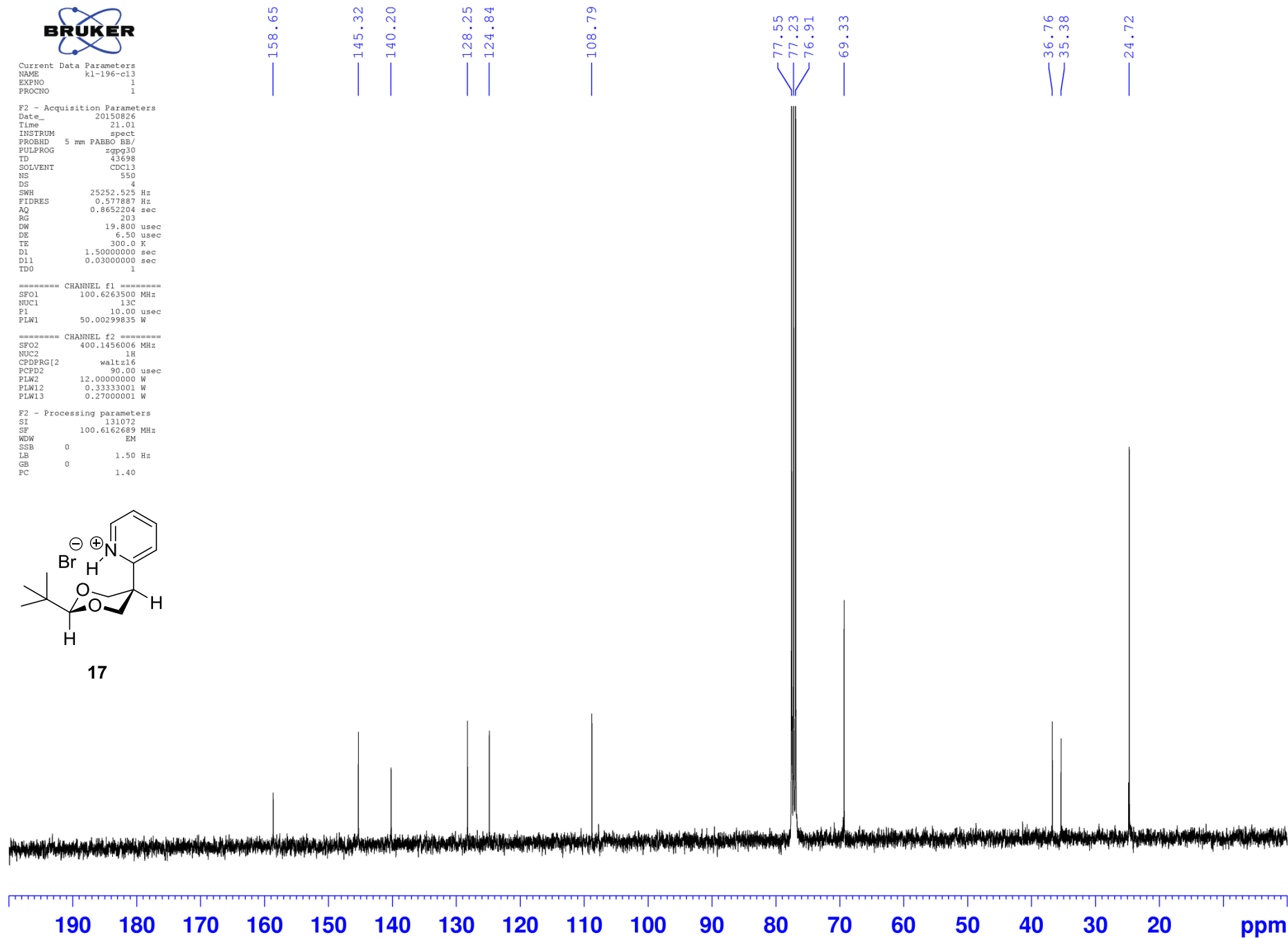
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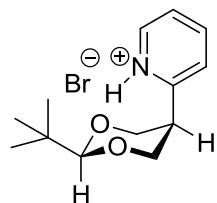
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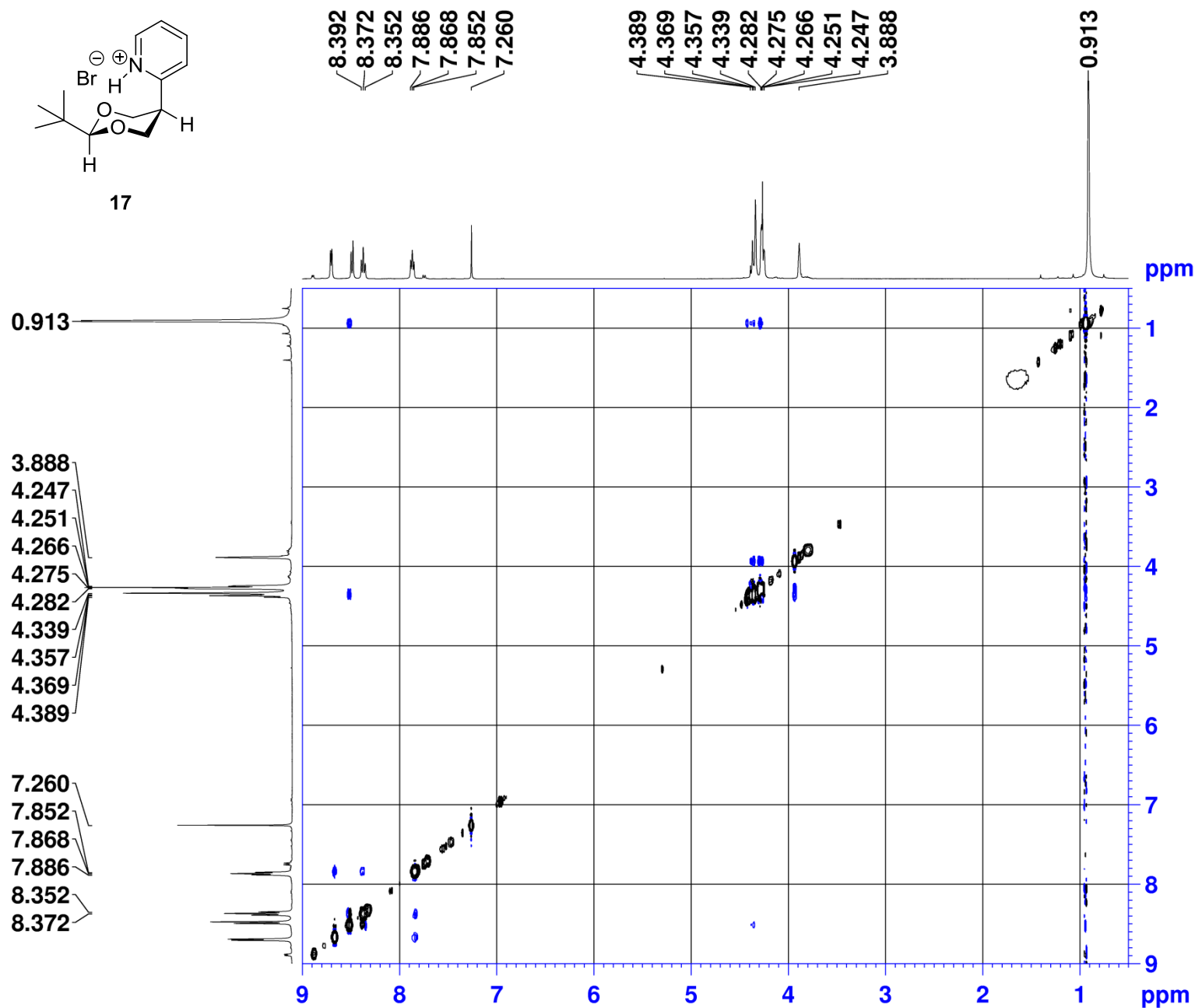


17





17



Current Data Parameters
NAME kl-196-HNOESY
EXPNO 1
PROCNO 1

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Time 21.21
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NS 4
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FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
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D0 0.00010330 sec
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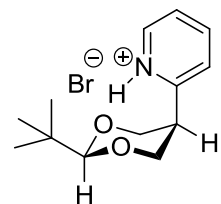
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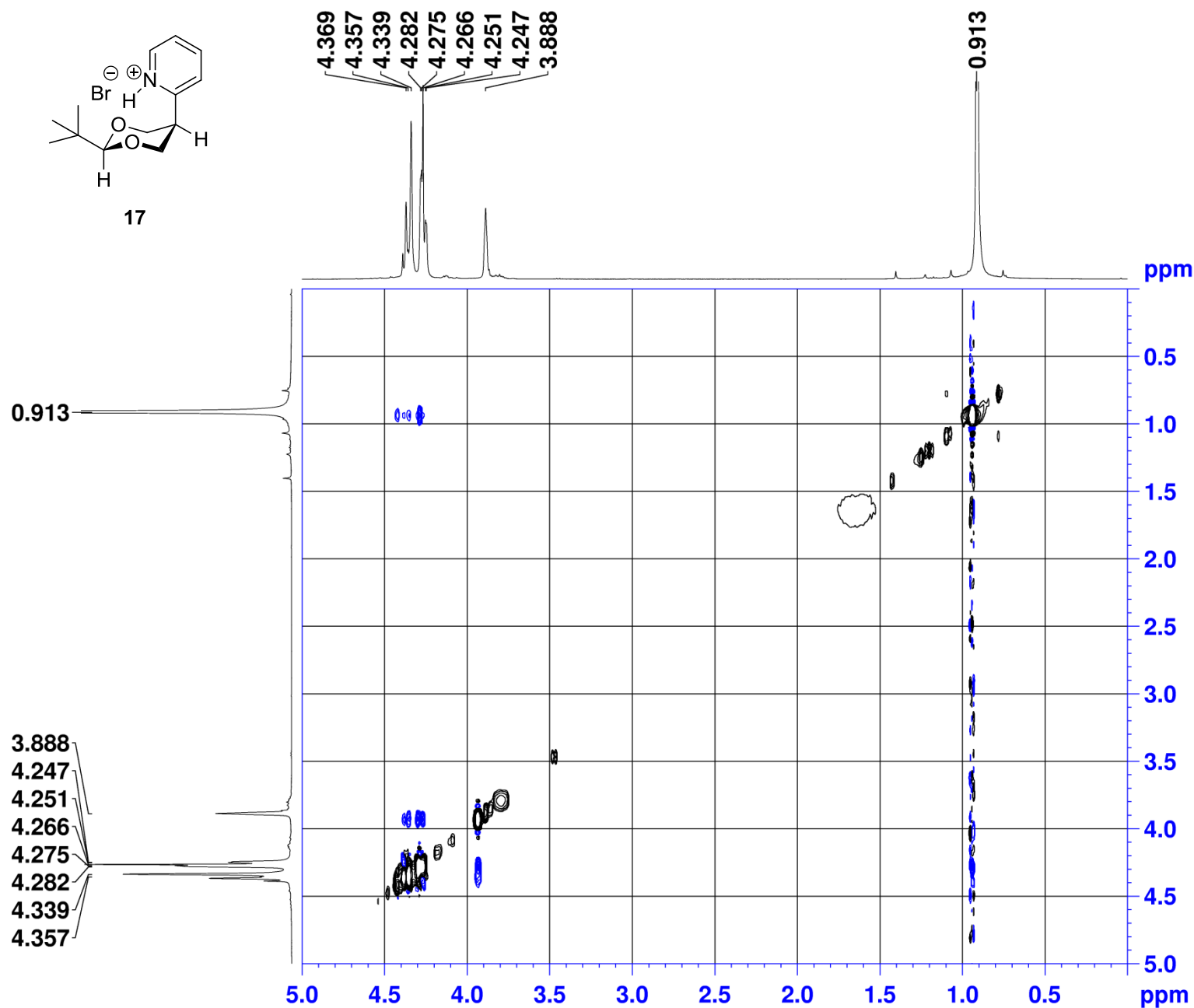
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SSB 2
LB 0 Hz
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FC 1.00

F1 - Processing parameters
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MC2 States-TPPI
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SSB 2
LB 0 Hz
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17



Current Data Parameters
NAME kl-196-HNOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150826
Time 21.21
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PULPROG noesygpphpp
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SOLVENT CDCl3
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SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
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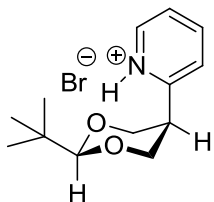
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PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
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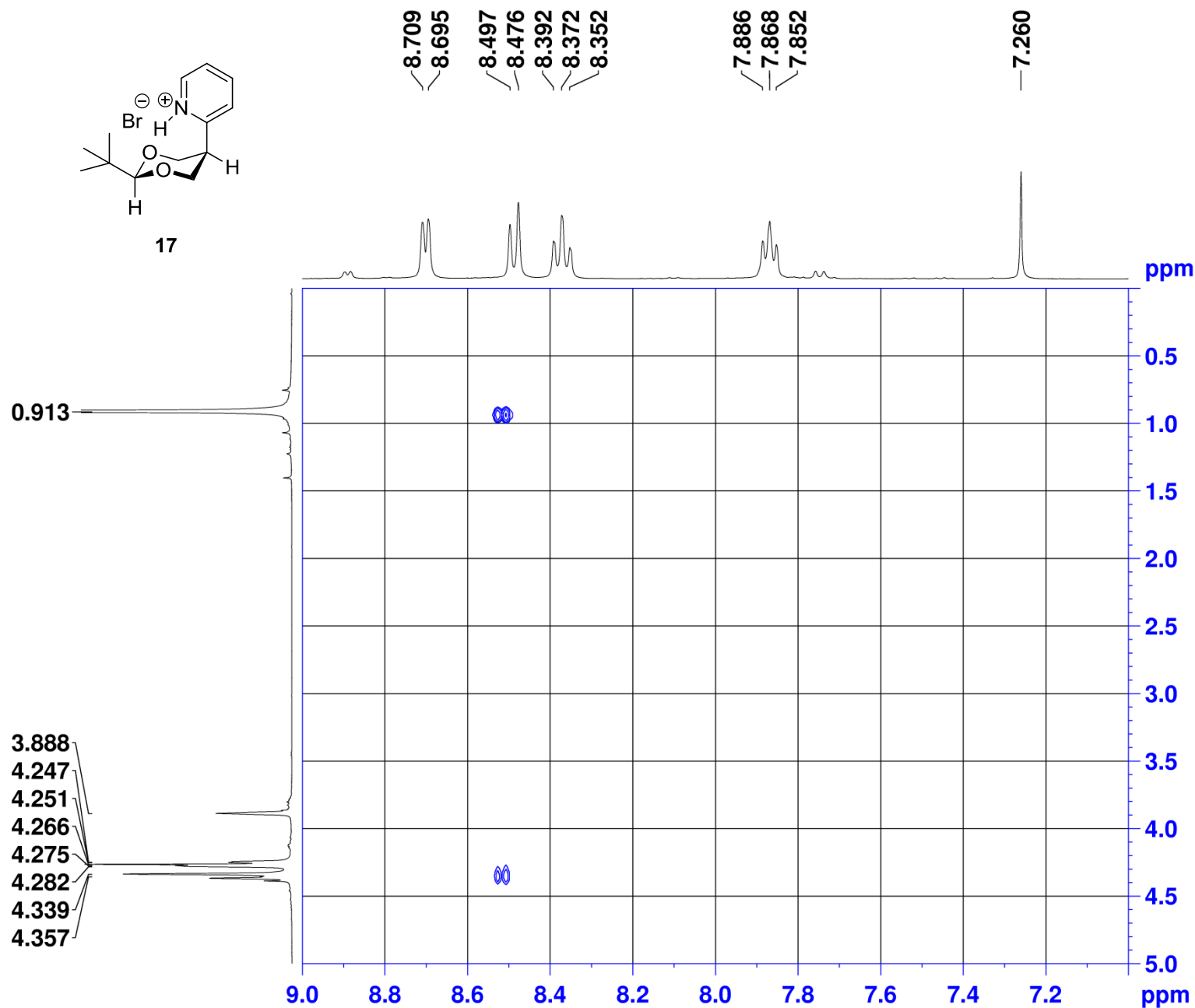
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SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
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SF 400.1440081 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440090 MHz
WDW
SSB 2
LB 0 Hz
GB 0



17



Current Data Parameters
NAME kl-196-HNOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150826
Time 21.21
INSTRUM spect
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PULPROG noesygpphph
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
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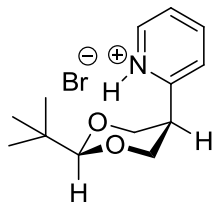
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===== GRADIENT CHANNEL =====
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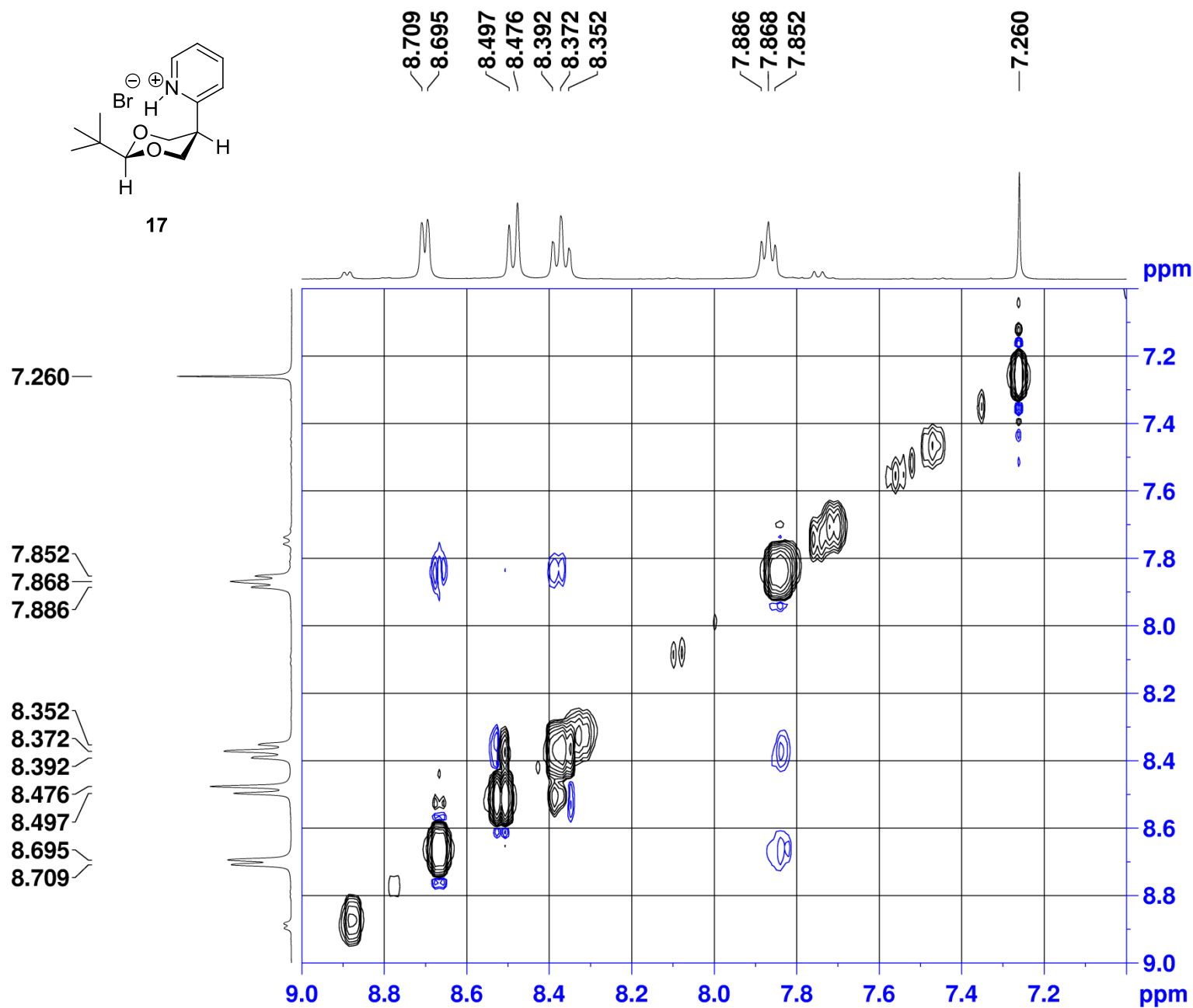
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SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
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SF 400.1440081 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440090 MHz
WDW
SSB 2
LB 0 Hz
GB 0



17



Current Data Parameters
NAME kl-196-HNOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20150826
Time 21.21
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG noesygpph
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W
===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440081 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
FC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440090 MHz
WDW
SSB 2
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Current Data Parameters
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PROCNO 1

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FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNST2 145.000000
CNST17 -0.5000000
D0 0.00000300 sec
D1 1.00000000 sec
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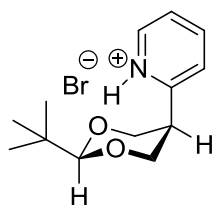
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P63 1500.00 usec
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PLW2 50.00000000 W
PLW12 0.78125000 W
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SPOAL7 Crp60deep.4
SPOAL7 0.500
SPOFFS7 0 Hz
SPW7 7.63940001 W
SPNAM[14] Crp32,1.5,20.2
SPOAL14 0.500
SPOFFS14 0 Hz
SPW14 3.25950003 W
SPOAL18 Crp60_kfilt.2
SPOAL18 0.500
SPOFFS18 0 Hz
SPW18 1.83050001 W
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SPOAL31 0.500
SPOFFS31 0 Hz
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
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GPNAM[3] SMSQ10.100
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GP23 11.00 %
GP24 5.00 %
P16 1000.00 usec
P19 600.00 usec

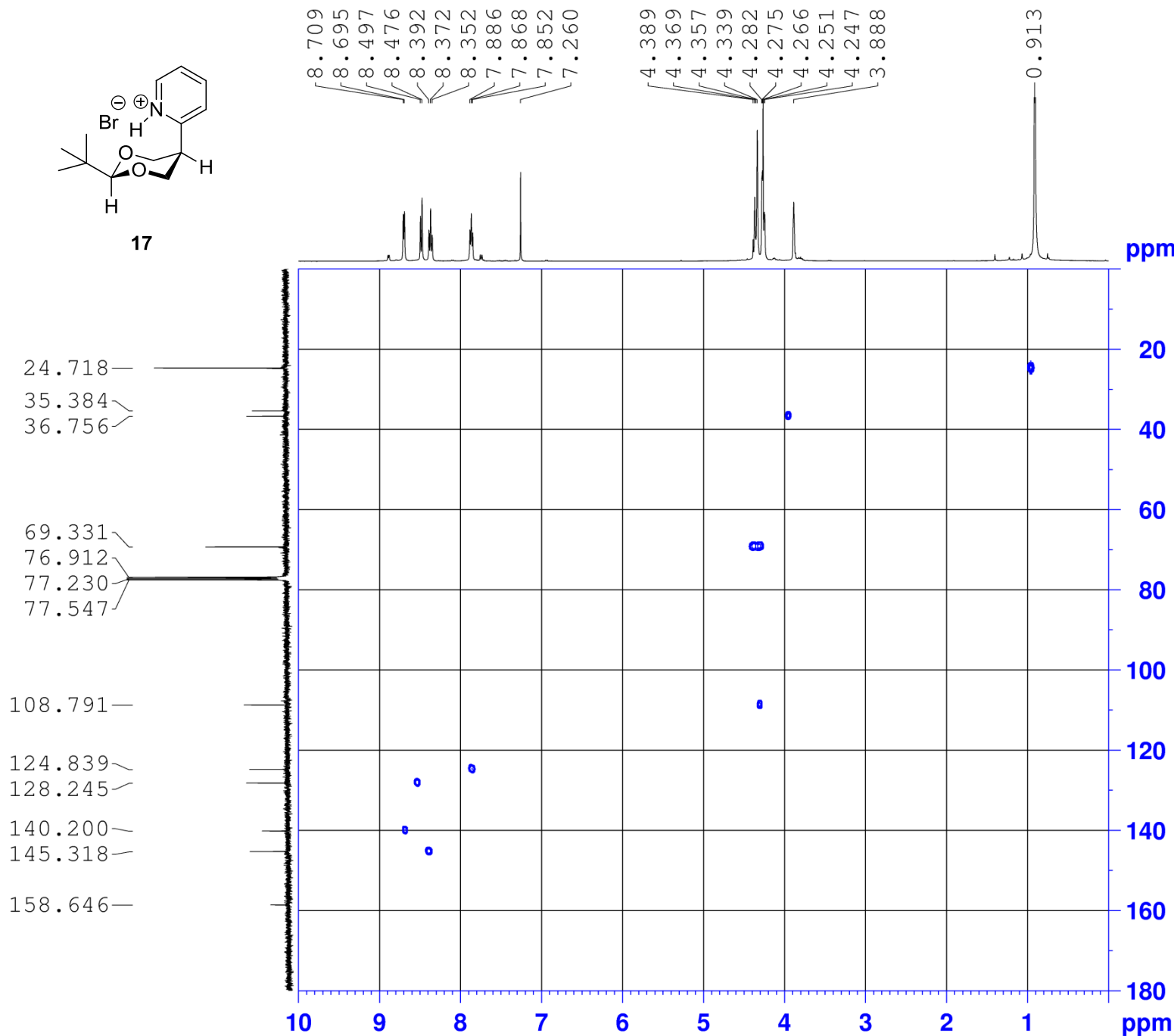
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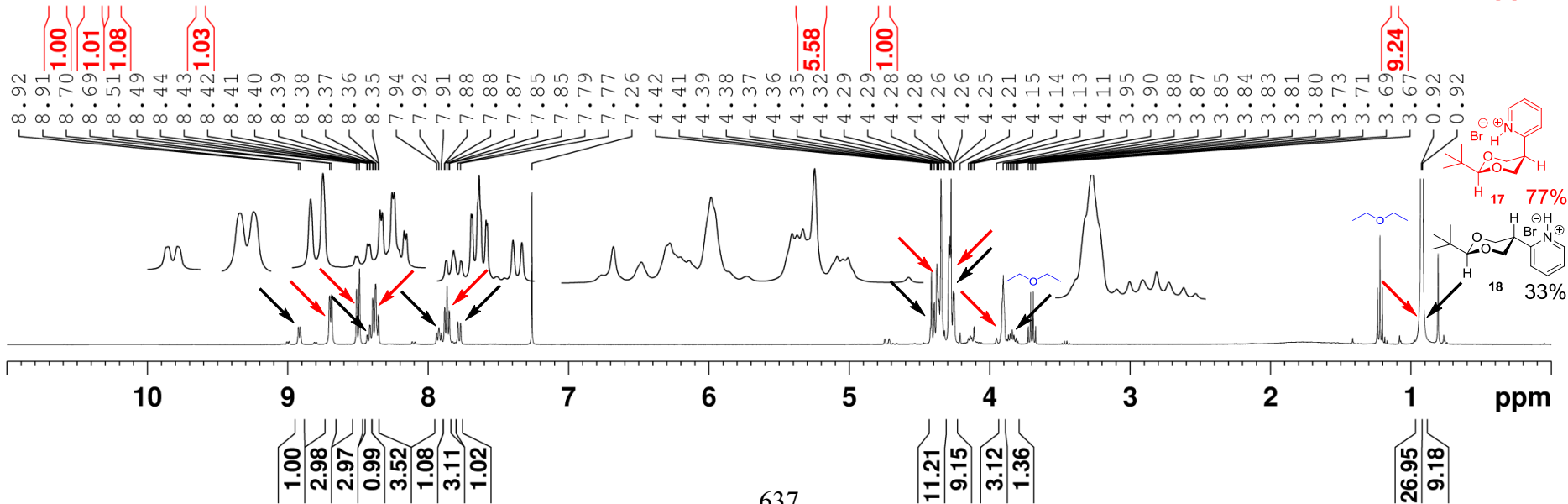
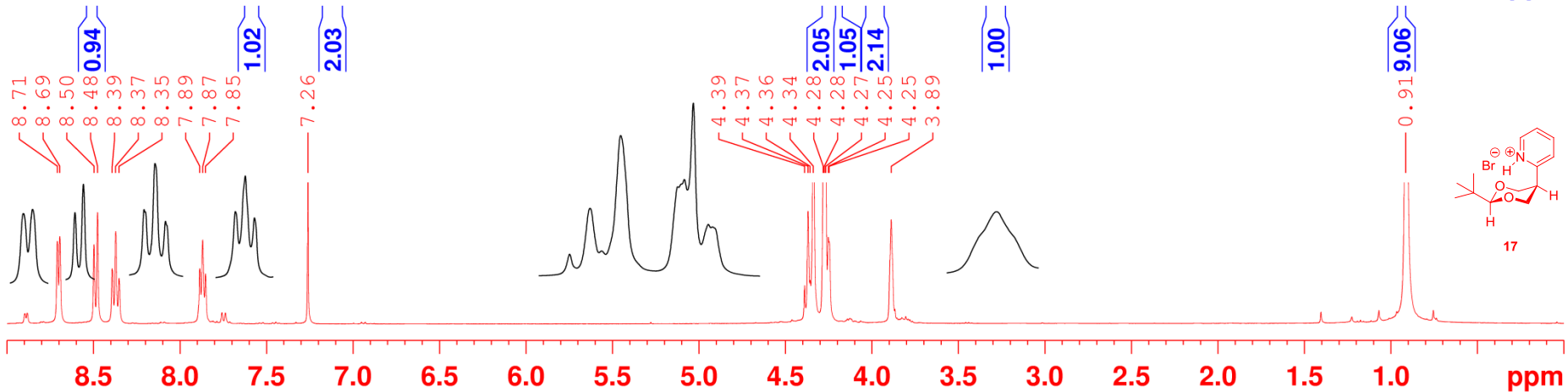
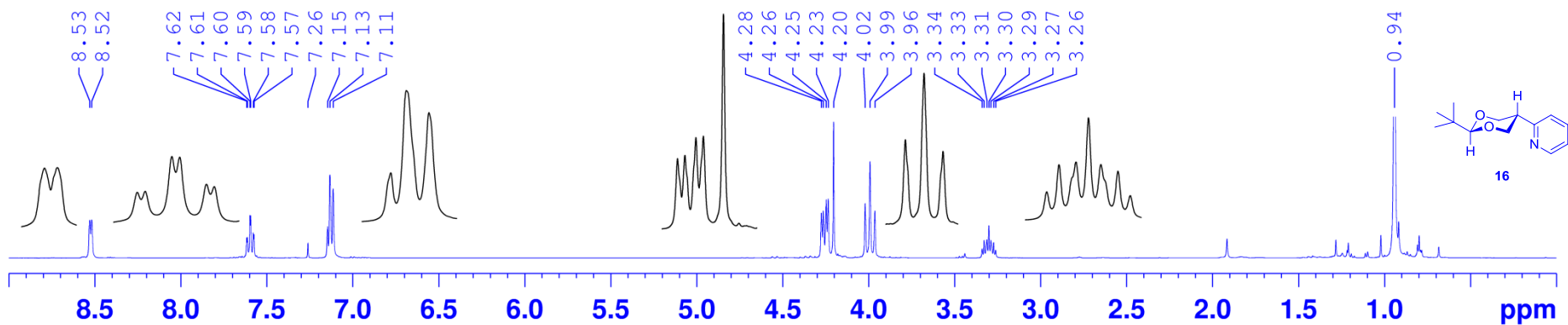
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LB 0 Hz
GB 0
PC 1.40

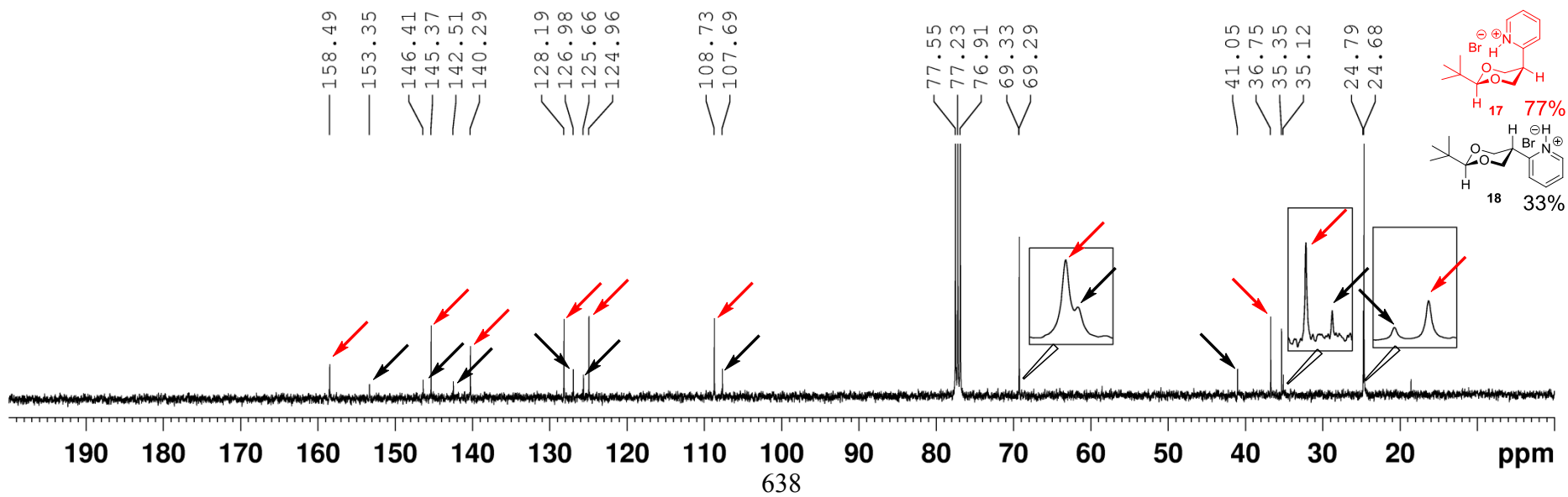
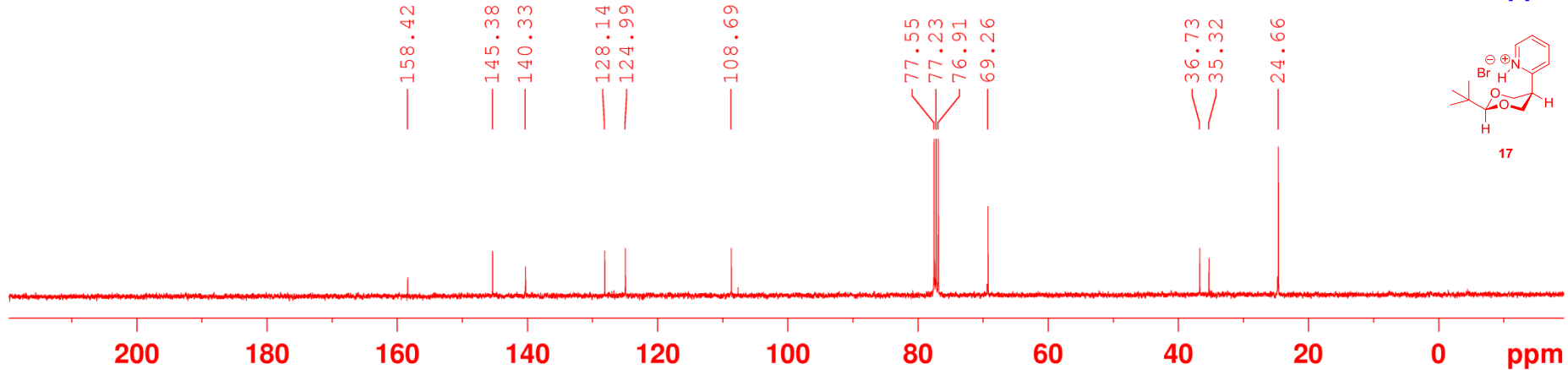
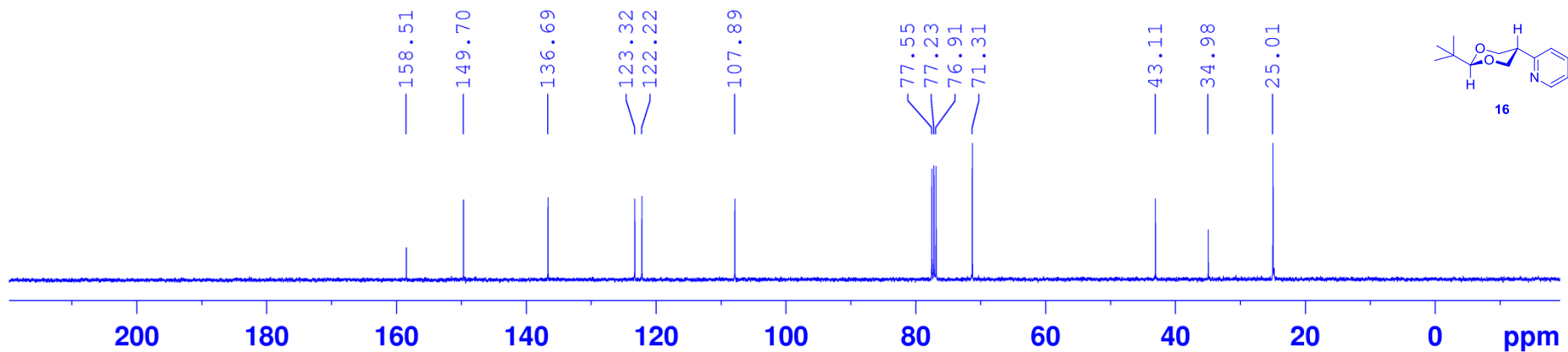
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WDW States
SSB 2
LB 0 Hz
GB 0



17







2.4 The Anomeric Effect Revisited

General Procedures

Anhydrous solvents were obtained as follows: dry Et₂O and THF were freshly distilled from a dark-purple solution of sodium and benzophenone; cyclohexane and pentane were dried over anhydrous magnesium sulfate, filtered, and freshly distilled from a dark blue solution of sodium/benzophenone/tetraglyme; acetonitrile was distilled from calcium hydride. NMR spectra were recorded in CDCl₃ on a 400 MHz spectrometer, unless otherwise noted and chemical shifts are reported in ppm. Proton spectra are referenced to the residual ¹H signal of CHCl₃ at δ = 7.26 and are reported relative to TMS at δ = 0.00; carbon spectra are referenced to the ¹³C signal for CDCl₃ at δ = 77.23 and are reported relative to TMS at δ = 0.00; fluorine spectra are referenced to a fluorobenzene internal standard at δ = -113.15 and are reported relative to CCl₃F at δ = 0.00. Residual acid present in the CDCl₃ NMR solvent was neutralized with the addition of and storage over anhydrous potassium carbonate to prevent epimerization of products. Column chromatography was conducted using neutral alumina or silica gel as specified. HRMS molecular mass determinations were performed on a TOF mass spectrometer using a direct analysis in real time (DART) ionization method. Refractive indices and melting points are uncorrected. All numbered compounds in this section originate from Section 1-5 above.

Equilibrations

For each pair of anomeric diastereomers, equilibrium was approached independently from pure samples of each isomer. The diastereomers were equilibrated at room temperature (~23 °C) in sealed vials or ampoules as solutions in dry cyclohexane, pentane, Et₂O, THF or CH₃CN over the specified catalyst. The diastereomeric pairs **1** and **2**, **3** and **4**, **11** and **12** were equilibrated under basic conditions in the given solvent over solid potassium *tert*-butoxide. Periodically, the samples were opened and neutralized by shaking with solid ammonium chloride. Compounds **5** and **6** were equilibrated in the given solvent over 10–20 beads of Amberlyst-15 resin and a spatula tip of magnesium sulfate to ensure anhydrous conditions. Periodically samples were opened and neutralized by shaking with anhydrous

K₂CO₃. Diastereomeric pairs **7** and **8**, **9** and **10** were equilibrated in the given solvent over solid anhydrous aluminum chloride. Periodically, samples were opened and quenched by addition to a 10 % aqueous solution of potassium carbonate, then dried over sodium sulfate.

The area ratio of the isomers was determined by GC analysis using one of the following columns: a 30 m x 0.25 mm x 0.25 µm Optima-225 50% cyanopropyl / 50% phenylmethyl polysiloxane column or a 30 m x 0.25 mm x 0.25 µm EC-1 100% dimethyl polysiloxane. The analysis parameters are detailed below. When the same area ratios were obtained from initially pure samples of each epimer, it was deemed that equilibrium had been attained. Area ratios for each equilibrium were taken as the average of 17 – 20 determinations from each side. The equilibrium constant for a system was calculated from the area ratio of that system and the free-energy difference was evaluated as $\Delta G^\circ = -RT \ln K$. All reported errors are propagated standard deviations.¹

Synthesis of Cyanocyclohexanes

***cis*-3,*cis*-5-Dimethylcyclohexanecarboxylic acid.** A solution of 10.010 g (66.7 mmol) of 3,5-dimethylbenzoic acid in 60 mL of EtOH containing a catalytic amount of acetic acid (ca. 0.1 mL) was prepared in a 500-mL Parr flask and hydrogenated over 307 mg of Pt₂O catalyst at room temperature and 60 psi for 18 h with shaking using a Parr apparatus. The reaction mixture was then filtered through a bed of Celite to remove the catalyst and the solvent was removed by rotary evaporation to afford 10.227 g (98%) of the title compound as a white, crystalline solid: mp 67.5–69.0 °C (EtOH) (lit.² 69.0–69.5 °C); ¹H NMR (400 MHz, CDCl₃) δ 0.58 (apparent q, *J* = 12.1 Hz, 1H), 0.92 (d, *J* = 6.5 Hz, 6H), 1.00 (apparent q, *J* = 12.5 Hz, 2H), 1.40–1.50 (m, 2H), 1.63–1.68 (m, 1H), 1.91–1.96 (m, 2H), 2.38 (tt, *J* = 12.3 Hz, *J* = 3.4 Hz, 1H), 11.33 (br s, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 22.6, 32.1, 37.0, 43.4, 43.5, 182.6; HRMS (DART-TOF) *m/z* calcd for C₉H₁₆O₂ [M + H]⁺ 157.1229, found 157.1224, *m/z* calcd for C₉H₁₆O₂ [M + NH₄]⁺ 174.1494, found 174.1507.

***cis*-3,*cis*-5-Dimethyl-1-(hydroxymethyl)cyclohexane.** A solution of 5.047 g (32.0 mmol) of *cis*,*cis*-3,5-dimethylcyclohexane-1-carboxylic acid in 100 mL of dry Et₂O was added to a 0 °C suspension

of 1.821 g (48.0 mmol) of lithium aluminum hydride in 150 mL of Et₂O. The resulting mixture was stirred at room temperature overnight and then hydrolyzed by sequential, dropwise addition of 6 mL of water, 6 mL of a 1 M aqueous solution of NaOH, and 9 mL of water. The mixture was filtered through a pad of Celite and the solids were washed with a 100-mL portion of Et₂O. The combined filtrate was rinsed with two 25-mL portions of brine, dried (Na₂SO₄), and concentrated under reduced pressure to yield 4.445 g (98%) of the title compound as a clear, colorless oil: $n_D^{21} = 1.4565$; ¹H NMR (400 MHz, CDCl₃) δ 0.51 (q, $J = 12.1$ Hz, 2H), 0.52 (q, $J = 12.1$ Hz, 1H), 0.89 (d, $J = 6.5$ Hz, 6H), 1.38–1.60 (m, 4H), 1.60–1.67 (m, 1H), 1.68–1.72 (m, 2H), 3.43 (d, $J = 6.3$ Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 22.9, 32.2, 38.1, 40.6, 44.4, 68.9; HRMS (DART-TOF) m/z calcd for C₉H₁₈O [M – H]⁺ 141.1279, found 141.1265, m/z calcd for C₉H₁₈O [2M + H]⁺ 285.2794, found 285.2789.

***cis*-3,*cis*-5-Dimethylcyclohexanecarbonitrile (2).** Following the conditions of our previously reported procedure,³ a mixture of 2.842 g (20.0 mmol) of *cis,cis*-3,5-dimethyl-1-(hydroxymethyl)cyclohexane, 15.091 g (50.3 mmol) of Bobbitt's salt, and 5.359 g (50.0 mmol) of 2,6-lutidine in 20 mL of CH₂Cl₂ was allowed to stir at room temperature overnight. The progress of the reaction was monitored by ¹H NMR and when full conversion to aldehyde was reached (ca. 12 h) the second oxidation was carried out. The reaction flask was charged with an additional 20 mL of CH₂Cl₂, 2.126 g of 2,6-lutidine (19.8 mmol), 15.241 g (50.8 mmol) of Bobbitt's salt, and 8.150 g (50.5 mmol) of hexamethyldisilazane (HMDS) then allowed to stir at room temperature. The reaction progress was monitored by ¹H NMR and upon completion (ca. 12 h) the majority of the solvent was removed using a rotary evaporator operating at room temperature and water aspirator pressure, but not to complete dryness (~10 mL of solvent remained). The mixture was triturated with 75 mL of Et₂O to precipitate the orange nitroxide and gravity filtered through a coarse filter paper into a separatory funnel to remove the solids. An additional 100 mL of Et₂O was added to the separatory funnel and the organic layer was washed sequentially with three 100-mL portions of a 2M aqueous HCl solution, two 100 mL portions of a saturated, aqueous NaHCO₃ solution, 100 mL of brine, and dried (Na₂SO₄). The solvent was carefully

removed using a rotary evaporator operating at room temperature and water aspirator pressure to afford an oil. The crude oil was distilled (Kugelrohr, bath temperature = 105 °C, 10 mm) to yield 786 mg (29 %) of the title compound as a clear, colorless oil: ^1H NMR (400 MHz, CDCl_3) δ 0.59 (apparent q, J = 11.8 Hz, 1H), 0.91 (d, J = 6.6 Hz, 6H), 1.09 (apparent q, J = 12.5 Hz, 2H), 1.34–1.47 (m, 2H), 1.61–1.68 (m, 1H), 1.96–2.04 (m, 2H), 2.44 (tt, J = 12.5 Hz, J = 3.6 Hz, 1H); ^{13}C NMR (100 MHz, CDCl_3) δ 22.2, 28.3, 31.8, 37.7, 42.8, 122.8; HRMS (DART-TOF) m/z calcd for $\text{C}_9\text{H}_{15}\text{N}$ $[\text{M} + \text{H}]^+$ 138.1283, found 138.1280, m/z calcd for $\text{C}_9\text{H}_{15}\text{N}$ $[\text{M} + \text{NH}_4]^+$ 155.1548, found 155.1554, m/z calcd for $\text{C}_9\text{H}_{15}\text{N}$ $[2\text{M} + \text{H}]^+$ 275.2487, found 275.2472.

***trans*-3,*trans*-5-Dimethylcyclohexanecarbonitrile (1).** To an oven-dried, argon-flushed 2-mL amber vial was added 200 mg (1.46 mmol) of *cis,cis*-3,5-dimethylcyclohexanecarbonitrile, 1 mL of Et_2O , and 50.0 mg (0.45 mmol) of solid potassium *tert*-butoxide. The vial was carefully flame-sealed and allowed to stand for 36 h, at which point, it was opened and the contents were transferred by pipette into a 3-mL vial containing 1 mL of distilled water and shaken. The top organic layer was carefully separated from the aqueous layer by pipette, dried (MgSO_4), transferred to a separate vial, and the title compound was isolated from this solution by preparative GC on a 10 ft \times 0.25 in. 15% FFAP on a non-acid-washed Chrom W (80–100 mesh) column using He as the carrier gas at a flow rate of 175 mL/min and an oven temperature of 140 °C: retention time of the *cis*-isomer (**2**) was 13.8 min and the *trans*-isomer (**1**) was 12.1 min. This process afforded 50.0 mg (25%) of the title compound as a clear, colorless oil: ^1H NMR (400 MHz, CDCl_3) δ 0.58 (apparent q, J = 12.1 Hz, 1H), 0.92 (d, J = 6.5 Hz, 6H), 1.07 (td, J = 12.7 Hz, J = 4.3 Hz, 2H), 1.70–1.77 (m, 1H), 1.78–1.87 (m, 2H), 1.88–1.95 (m, 2H), 2.95–3.01 (m, 1H); ^{13}C NMR (100 MHz, CDCl_3) δ 22.0, 27.6, 28.7, 36.1, 43.3, 122.6; HRMS (DART-TOF) m/z calcd for $\text{C}_9\text{H}_{15}\text{N}$ $[\text{M} + \text{H}]^+$ 138.1283, found 138.1289.

***cis*-3,*cis*-5-Bis(trifluoromethyl)cyclohexanecarboxylic acid.** A solution of 10.800 g (41.8 mmol) of 3,5-bis(trifluoromethyl)benzoic acid in 25 mL of trifluoroacetic acid was prepared in a 500-mL Parr flask and hydrogenated over 400 mg (0.176 mmol) of Pt_2O catalyst (10% on activated carbon) at

room temperature and 60 psi for 24 h with shaking using a Parr apparatus. The reaction mixture was then filtered through a Büchner funnel containing a medium porosity filter paper to remove the catalyst and the filter was rinsed with Et₂O. The solvent was removed by rotary evaporation to afford 10.878 g (98%) of the title compound as a white, crystalline solid: mp 98.2–99.7 °C (Et₂O / CF₃COOH); ¹H NMR (400 MHz, CDCl₃) δ 1.36 (apparent q, *J* = 13.3 Hz, 1H), 1.48 (apparent q, *J* = 13.0 Hz, 2H), 2.10–2.26 (m, 3H), 2.27–2.37 (m, 2H), 2.46 (tt, *J* = 12.6 Hz, *J* = 3.6 Hz, 1H), 9.66 (br s, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 23.5, 26.7 (quartet, *J*_{C–F} = 2.5 Hz), 40.5, 40.6 (quartet, *J*_{C–F} = 27.9 Hz), 126.8 (quartet, *J*_{C–F} = 278.5 Hz), 179.2; ¹⁹F NMR (376 MHz, CDCl₃) δ –73.8; HRMS (DART-TOF) *m/z* calcd for C₉H₁₀F₆O₂ [M + H]⁺ 264.0663, found 264.0664, *m/z* calcd for C₉H₁₀F₆O₂ [M + H₃O]⁺ 283.0769, found 283.0784.

***cis*-3,*cis*-5-Bis(trifluoromethyl)-1-(hydroxymethyl)cyclohexane.** A solution of 4.299 g (16.3 mmol) of *cis,cis*-3,5-bis(trifluoromethyl)cyclohexanecarboxylic acid in 100 mL of dry Et₂O was added to a 0 °C suspension of 1.235 g (32.6 mmol) of lithium aluminum hydride in 150 mL of Et₂O. The resulting mixture was stirred at room temperature overnight and then hydrolyzed by sequential, dropwise addition of 3 mL of water, 3 mL of a 1 M aqueous solution of NaOH, and 4.5 mL of water. The mixture was filtered through a pad of Celite and the solids were washed with a 100 mL portion of Et₂O. The combined filtrate was rinsed with two 25 mL portions of brine, dried (Na₂SO₄) and concentrated under reduced pressure to yield 3.824 g (94%) of the title compound as a clear, colorless oil: *n*_D²⁴ = 1.3915; ¹H NMR (400 MHz, CDCl₃) δ 1.07 (apparent q, *J* = 12.5 Hz, 2H), 1.32 (apparent q, *J* = 13.1 Hz, 1H), 1.46 (br s, 1H), 1.58–1.70 (m, 1H), 2.00–2.09 (m, 2H), 2.10–2.23 (m, 3H), 3.58 (d, *J* = 5.6 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 24.1 (apparent septet, *J*_{C–F} = 2.6 Hz), 27.4 (quartet, *J*_{C–F} = 2.4 Hz), 38.1, 40.8 (quartet, *J*_{C–F} = 27.5 Hz), 67.3, 127.2 (quartet, *J*_{C–F} = 278.1 Hz); ¹⁹F NMR (376 MHz, CDCl₃) δ –73.9; HRMS (DART-TOF) *m/z* calcd for C₉H₁₂F₆O [M + H]⁺ 251.0871, found 251.0864.

***cis*-3,*cis*-5-Bis(trifluoromethyl)cyclohexanecarbonitrile (4).** Following the conditions of our previously reported procedure,³ a mixture of 2.526 g (10.1 mmol) of *cis,cis*-3,5-bis(trifluoromethyl)-1-(hydroxymethyl)cyclohexane, 7.514 g (25.0 mmol) of Bobbitt's salt, and 2.659 g (24.8 mmol) of 2,6-

lutidine in 20 mL of CH₂Cl₂ was allowed to stir at room temperature overnight. The progress of the reaction was monitored by ¹H NMR and when full conversion to aldehyde was reached (ca. 12 h) the second oxidation was carried out. The reaction flask was charged with an additional 20 mL of CH₂Cl₂, 1.183 g of 2,6-lutidine (11.0 mmol), 7.489 g (25.0 mmol) of Bobbitt's salt, and 4.107 g (25.4 mmol) of hexamethyldisilazane (HMDS) then stirred at room temperature. The reaction progress was monitored by ¹H NMR, and upon completion (ca. 12 h) the majority of the solvent was removed using a rotary evaporator operating at room temperature and water aspirator pressure, but not to complete dryness (~10 mL of solvent remained). The mixture was triturated with 75 mL of Et₂O to precipitate the orange nitroxide and gravity filtered through a coarse filter paper into a separatory funnel to remove the solids. An additional 100 mL of Et₂O was added to the separatory funnel and the organic layer was sequentially washed with three 100-mL portions of a 2M aqueous HCl solution, two 100 mL portions of a saturated, aqueous NaHCO₃ solution, 100 mL of brine, and dried over Na₂SO₄. The solvent was carefully removed via a rotary evaporator operating at room temperature and water aspirator pressure to afford an off-white solid. The crude solid was distilled (Kugelrohr, bath temperature = 130–140 °C, 10 mm) to yield 1.728 g (71%) of the title compound as a crystalline, white solid: mp 82.5–83.8 °C (Et₂O); ¹H NMR (400 MHz, CDCl₃) δ 1.39 (apparent q, *J* = 12.6 Hz, 1H), 1.62 (apparent q, *J* = 12.8 Hz, 2H), 2.08–2.24 (m, 3H), 2.33–2.42 (m, 2H), 2.58 (tt, *J* = 12.7 Hz, *J* = 3.6 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 23.1, 26.5, 27.8, 40.2 (quartet, *J*_{C-F} = 27.5 Hz), 120.0, 126.2 (quartet, *J*_{C-F} = 278.7 Hz); ¹⁹F NMR (376 MHz, CDCl₃) δ –73.8; HRMS (DART-TOF) *m/z* calcd for C₉H₉F₆N [M + H]⁺ 246.0717, found 246.0740.

***trans*-3,*trans*-5-Bis(trifluoromethyl)cyclohexanecarbonitrile (3).** To a 15-mL oven-dried vial was added 258 mg (1.05 mmol) of *cis,cis*-3,5-bis(trifluoromethyl)cyclohexanecarbonitrile, 10 mL of Et₂O, and 250 mg (2.22 mmol) of solid potassium *tert*-butoxide. The vial was sealed with a septum and allowed to stand for 36 h, at which point, it was opened and the contents were poured into a separate 25-mL vial containing 10 mL of water. The top organic layer was carefully separated from the aqueous layer by pipette, dried (MgSO₄), and transferred to a separate vial to be concentrated (ca. 4–5 mL of solvent),

and the title compound was isolated from this solution by preparative GC on a 10 ft \times 0.25 in. 15% FFAP on a non-acid-washed Chrom W (80–100 mesh) column using He as the carrier gas at a flow rate of 185 mL/min and an oven temperature of 110 °C: retention time of the *cis*-isomer (**4**) was 11.7 min and the *trans*-isomer (**3**) was 5.0 min. This process afforded 48.0 mg (19%) of the title compound as a crystalline, white solid: mp 59.0–59.7 °C (sublimation); ^1H NMR (400 MHz, CDCl_3) δ 1.39 (apparent q, $J = 13.0$ Hz, 1H), 1.58 (td, $J = 13.3$ Hz, $J = 4.5$ Hz, 2H), 2.21–2.31 (m, 3H), 2.46–2.62 (m, 2H), 3.25–3.32 (m, 1H); ^{13}C NMR (100 MHz, CDCl_3) δ 23.5 (apparent septet, $J_{\text{C-F}} = 2.6$ Hz), 25.6, 26.8 (quartet, $J_{\text{C-F}} = 2.2$ Hz), 37.7 (quartet, $J_{\text{C-F}} = 28.3$ Hz), 119.8, 126.6 (quartet, $J_{\text{C-F}} = 278.6$ Hz); ^{19}F NMR (376 MHz, CDCl_3) δ –73.7; HRMS (DART-TOF) m/z calcd for $\text{C}_9\text{H}_9\text{F}_6\text{N}$ $[\text{M} + \text{H}]^+$ 246.0717, found 246.0704.

Synthesis of 2-Methoxy-1,3-dioxanes

***r*-2-Methoxy-*trans*-4,*trans*-6-dimethyl-1,3-dioxane (5)** and ***r*-2-Methoxy-*cis*-4,*cis*-6-dimethyl-1,3-dioxane (6)**. Following a procedure developed by Eliel and Nader⁴ with minor modifications, a mixture of 2.621 g of *meso*-2,4-pentanediol,⁵ 2.991 g (27.5 mmol) of trimethylorthoformate, 116 mg (0.61 mmol) of *p*-TsOH, and 100 mL of cyclohexane was heated at reflux for 1 h under a 10-mL Dean-Stark trap. After 1 h of refluxing, the contents of the trap were discarded and the trap was allowed to refill; this process was repeated twice more allowing for ca. 30 mL of a MeOH/solvent mixture to be discarded. The reaction mixture was then allowed to cool to room temperature, 1.50 g of solid, anhydrous K_2CO_3 was added, and the mixture was stirred for 1.5 h. The solvent was then carefully removed through use of a rotary evaporator operating at room temperature and water aspirator pressure to afford 2.578 g (70%) of a clear oil containing a mixture of compounds **5** and **6**. The title compounds are extremely acid-sensitive and to prevent decomposition due to any adventitious acid, a spatula-tip of anhydrous, solid K_2CO_3 was added to all glassware in which the title compound was transferred. Separation of compounds **5** and **6** was achieved by careful column chromatography (200 g neutral alumina, $5 \rightarrow 20\%$ Et_2O /hexanes); 50 mL fractions were collected into glassware containing a small quantity of anhydrous, solid K_2CO_3 : 863 mg (ca. 24%) of pure *trans*-isomer (**5**) was collected in fractions 5–9; 101 mg (ca. 3%) of pure *cis*-isomer (**6**)

was collected in fraction 16. Progress of the chromatography was monitored by TLC (neutral alumina, eluent: 15% Et₂O in hexanes) and visualization of **5** and **6** was achieved by two possible methods: an I₂ chamber or staining with a solution of 20% phosphomolybdic acid in EtOH followed by heating. The *trans*-isomer (**5**), which streaks on alumina, had an R_f = 0.41 and the *cis*-isomer (**6**) had an R_f = 0.15.

***r*-2-Methoxy-*trans*-4,*trans*-6-dimethyl-1,3-dioxane⁴ (**5**):** clear, colorless oil; ¹H NMR (400 MHz, CDCl₃) δ 1.15 (d, *J* = 6.3 Hz, 6H), 1.32 (dt, *J* = 13.1 Hz, *J* = 11.5 Hz, 1H), 1.54 (apparent dtd, *J* = 13.1, Hz, *J* = 2.5 Hz, *J* = 1.4 Hz, 1H), 3.30 (s, 12 h 3H), 4.18 (dq, *J* = 11.7 Hz, *J* = 6.1 Hz, *J* = 2.4 Hz, 2H), 5.37 (s, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 21.6, 40.2, 53.0, 64.2, 109.4.

***r*-2-Methoxy-*cis*-4,*cis*-6-dimethyl-1,3-dioxane⁴ (**6**):** white, crystalline solid; mp 38.3–38.8 °C (sublimation) (lit.⁴ 38–39 °C); ¹H NMR (400 MHz, CDCl₃) δ 1.25 (dt, *J* = 13.0 Hz, *J* = 11.1 Hz, 1H), 1.26 (d, *J* = 6.1 Hz, 6H), 1.54 (dt, *J* = 13.1, Hz, *J* = 2.4, 1H), 3.50 (s, 3H), 3.85 (dq, *J* = 11.1 Hz, *J* = 6.1 Hz, *J* = 2.4 Hz, 2H), 5.16 (s, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 21.3, 39.6, 53.2, 71.2, 112.1.

***d,l*-1,1,1,5,5,5-Hexafluoro-2,4-pentanediol** and ***meso*-1,1,1,5,5,5-Hexafluoro-2,4-pentanediol.**⁶

Following a modification of a procedure reported by Murphy,⁶ a solution of 400 mL of MeOH and 100 mL of deionized water was prepared in a 2-L two-neck, round-bottomed flask fitted with a mechanical stirrer. The solution was made basic by addition of 0.550 g (13.8 mmol) of solid NaOH, cooled to –78 °C, and then, while stirring, 9.309 g (246 mmol) of solid NaBH₄ was added in portions. A solution of 41.612 g (200 mmol) of 1,1,1,5,5,5-hexafluoropentanedione in 100 mL of MeOH was prepared, cooled to –10 °C, and added to a 200-mL addition funnel. The addition funnel was then fitted to the second neck of the reaction flask and the dione was added at a rate of 50 mL/h to the stirred reaction mixture. The reaction mixture was kept at –78 °C for ca. 12 h, and then allowed to warm to room temperature. After 18 h, the addition funnel was removed and 400 mL of a 10% aqueous HCl solution was slowly added to the reaction mixture over a period of 20 min. to quench the excess NaBH₄ and allowed to stir for 1 h to hydrolyze the borate ester. The resulting solution was then transferred to a round-bottomed flask and the MeOH was removed using a rotary evaporator operating at 35 °C and water aspirator pressure. The

remaining solution was then transferred to a large separatory funnel and was extracted with five 100-mL portions of Et₂O. The organic layers were combined, 75 mL of hexanes was added and the solvent was removed under reduced pressure; this process was repeated twice to azeotropically remove any excess water or MeOH. The crude oil was directly distilled (Kugelrohr, bath temperature = 65–100 °C, 10 mm) to afford 29.560 g (70%) of a mixture (55 : 45; *d,l* : *meso*) of the title compounds as a clear oil that partially crystallizes upon standing: ¹H NMR (400 MHz, CD₂Cl₂) δ 1.96–2.05 (m, 3H), 2.16 (dt, *J* = 14.8 Hz, *J* = 3.1 Hz, 1H), 2.75 (d, *J* = 5.8 Hz, 2H), 3.24 (d, *J* = 3.9 Hz, 2H), 4.25–4.40 (m, 4H); ¹³C NMR (100 MHz, CD₂Cl₂) δ 29.3, 29.4, 66.6 (quartet, *J*_{C-F} = 32.1 Hz), 69.4 (quartet, *J*_{C-F} = 32.1 Hz), 124.4 (quartet, *J*_{C-F} = 281.3 Hz), 125.1 (quartet, *J*_{C-F} = 281.3 Hz); ¹⁹F NMR (376 MHz, CD₂Cl₂) δ –79.7, –80.1; HRMS (DART-TOF) *m/z* calcd for C₅H₆F₆O₂ [M + H]⁺ 213.0350, found 213.0343.

***r*-2-Phenyl-*cis*-4,*cis*-6-bis(trifluoromethyl)-1,3-dioxane.**⁶ Following a modification of a procedure reported by Murphy⁶, a mixture of 29.506 g (139.1 mmol) of 1,1,1,5,5,5-hexafluoro-2,4-pentanediol, consisting of ~ 55% racemic and ~ 45% *meso* isomers, 9.045 g (59.5 mmol) of benzaldehyde dimethyl acetal, 120 mg (0.63 mmol) of *p*-TsOH in 150 mL of hexanes was heated at reflux under a Dean–Stark trap⁷ for 12 h, at which point the reaction mixture was allowed to cool to room temperature. Upon cooling to room temperature, off-white, needle-like crystals formed upon the walls of the reaction flask, and after 3 h of standing, the flask was further allowed to cool to 5 °C in a cold water bath resulting in further crystallization. The contents of the flask were then filtered through a Büchner funnel containing a coarse filter paper, and the crystals that had collected in the filter were rinsed with 50 mL of cold hexanes,⁸ and allowed to air-dry, affording 17.805 g (95%) of an off-white, crystalline solid (mp 97.0–99.0 °C; hexanes). ¹H NMR analysis revealed that the product was contaminated with ~ 10% by mass of racemic 1,1,1,5,5,5-hexafluoro-2,4-pentanediol. Further purification was achieved as follows: the solid was dissolved in CH₂Cl₂, the solution was extracted with three 100 mL portions of a saturated, aqueous NaHCO₃ solution,⁹ dried over anhydrous Na₂SO₄, and solvent removed by rotary evaporation to afford 9.737 g (52%) of the title compound as a white, crystalline solid: mp 100.5–101.5 °C (CH₂Cl₂); ¹H

NMR (400 MHz, CDCl₃) δ 2.00 (dt, J = 12.9 Hz, J = 2.8 Hz, 1H), 2.11 (dt, J = 13.0 Hz, J = 11.6, 1H), 4.35 (dq, J = 11.6 Hz, J = 5.7 Hz, J = 3.1 Hz, 2H), 5.64 (s, 1H), 7.38–7.43 (m, 3H) 7.48–7.54 (m, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 22.9, 73.6 (quartet, J_{C-F} = 34.0 Hz), 101.3, 123.1 (quartet, J_{C-F} = 278.9 Hz), 126.5, 128.6, 130.0, 135.8; ¹⁹F NMR (376 MHz, CDCl₃) δ –79.4; HRMS (DART-TOF) m/z calcd for C₁₂H₁₀F₆O₂ [M + H]⁺ 301.0663, found 301.0672.

***meso*-1,1,1,5,5,5-Hexafluoro-2,4-pentanediol.**⁶ A solution of 9.506 g (31.7 mmol) of *r*-2-phenyl-*cis,cis*-4,6-bis(trifluoromethyl)-1,3-dioxane, 5 mL of deionized water, 10 mL of a 10% aqueous HCl solution, and 150 mL of MeOH were refluxed for 48 h. The solution was then allowed to cool to room temperature, 100 mL of hexanes was added, and the solvent was removed under reduced pressure; this process was repeated twice to azeotropically remove any excess water or MeOH. The mixture was then diluted with 200 mL of water, transferred to a separatory funnel, and the aqueous layer was extracted with four 75 mL portions of hexanes.¹⁰ The organic extracts were discarded and the remaining aqueous solution was extracted with three 100 mL portions of Et₂O, the organic layers were combined, dried (Na₂SO₄), 100 mL of hexanes was added, and the solvent was removed under reduced pressure; this process was repeated twice to azeotropically remove any excess water. The clear oil solidified on cooling to –78 °C and the last traces of solvent were removed under high vacuum while allowing the flask to warm to ~ 20 °C affording 6.47 g (96%) of the title compound as a white, crystalline solid: mp 24.3–25.5 °C (Et₂O); ¹H NMR (400 MHz, CD₂Cl₂) δ 2.00 (dt, J = 14.8 Hz, J = 9.9 Hz, 1H), 2.15 (dt, J = 14.8 Hz, J = 3.1, 1H), 3.25 (d, J = 3.9 Hz, 2H), 4.26–4.35 (m, 2H); ¹³C NMR (100 MHz, CD₂Cl₂) δ 29.4, 69.4 (quartet, J_{C-F} = 32.1 Hz), 101.3, 124.4 (quartet, J_{C-F} = 281.3 Hz); ¹⁹F NMR (376 MHz, CD₂Cl₂) δ –80.2; HRMS (DART-TOF) m/z calcd for C₅H₆F₆O₂ [M + H]⁺ 213.0350, found 213.0369.

***r*-2-Methoxy-*trans*-4,*trans*-6-bis(trifluoromethyl)-1,3-dioxane (7)** and ***r*-2-Methoxy-*cis*-4,*cis*-6-bis(trifluoromethyl)-1,3-dioxane (8).** A flame-dried, argon-flushed, round-bottomed flask containing a magnetic stir bar was charged with 1.552 g (7.31 mmol) of *meso*-1,1,1,5,5,5-hexafluoro-2,4-pentanediol and 3.753 g (35.4 mmol) of trimethylorthoformate. The neat mixture was stirred for 5 min. to dissolve the

diol, then 0.1 mL (ca. 43.5 mg, 0.31 mmol) of a 49 wt/wt% solution of borontrifluoride etherate in Et₂O was added via syringe and the mixture was stirred for 2 h at room temperature. At which point, under a cone of argon gas, ~ 0.50 g of solid, anhydrous K₂CO₃ was added and the mixture was stirred under a gentle flow of argon until bubbling of the mixture ceased. The mixture is then diluted with 15 mL of pentane and the contents of the flask are transferred to a separatory funnel, diluted with an additional 150 mL of pentane, and rinsed with three portions of a 10% aqueous K₂CO₃ solution. The pentane layer was checked by GC-MS to ensure no excess diol remained,¹¹ then rinsed with a 25 mL portion of brine, and dried over Na₂SO₄. The title compounds are extremely acid-sensitive and to prevent decomposition due to any adventitious acid, a spatula-tip of anhydrous, solid K₂CO₃ was added to all glassware in which the title compound was transferred. The solvent is carefully removed via use of a rotary evaporator operating at ~ 15 °C and water aspirator pressure to afford ~ 1.2 g of a light yellow oil containing a mixture of trimethyl orthoformate, and a mixture of the *trans* (**7**) and *cis* (**8**) title compounds in an approximately 5:1 ratio respectively.¹² Separation of compounds **7** and **8** was achieved by careful column chromatography (75 g neutral alumina, 0 → 10% Et₂O/pentane); 20 mL fractions were collected into glassware containing a small quantity of anhydrous, solid K₂CO₃: 286 mg (ca. 16 %) of pure *trans*-isomer (**7**) was collected in fractions 7–8; 68 mg (ca. 4%) of pure *cis*-isomer (**8**) was collected in fractions 26–42. Progress of the chromatography was monitored by GC-MS¹³ as TLC visualization methods were insufficient.

***r*-2-Methoxy-*trans*-4,*trans*-6-bis(trifluoromethyl)-1,3-dioxane (**7**):** clear, colorless oil; ¹H NMR (400 MHz, CDCl₃) δ 1.91 (dtd, *J* = 12.9 Hz, *J* = 2.2 Hz, *J* = 1.0 Hz, 1H), 2.03 (dt, *J* = 12.5 Hz, *J* = 12.1, 1H), 3.42 (s, 3H), 4.56 (dq, *J* = 11.8 Hz, *J* = 5.8 Hz, *J* = 2.9 Hz, 2H), 5.61 (s, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 22.2, 53.8, 65.5 (quartet, *J*_{C-F} = 34.4 Hz), 108.8, 123.4 (quartet, *J*_{C-F} = 278.3 Hz); ¹⁹F NMR (376 MHz, CDCl₃) δ -79.9; HRMS (DART-TOF) *m/z* calcd for C₇H₈F₆O₃ [M + H]⁺ 255.0456, found 255.0438.

***r*-2-Methoxy-*cis*-4,*cis*-6-bis(trifluoromethyl)-1,3-dioxane (**8**):** white, crystalline solid; mp 27.7–28.4 °C (pentane); ¹H NMR (400 MHz, CDCl₃) δ 1.90 (dt, *J* = 13.0 Hz, *J* = 3.1 Hz, 1H), 1.98 (dt, *J* = 12.8

Hz, $J = 11.7$, 1H), 3.55 (s, 3H), 4.26 (dq, $J = 11.4$ Hz, $J = 5.6$ Hz, $J = 3.1$ Hz, 2H), 5.38 (s, 1H); ^{13}C NMR (100 MHz, CDCl_3) δ 22.1, 52.5, 71.8 (quartet, $J_{\text{C-F}} = 34.6$ Hz), 110.6, 122.8 (quartet, $J_{\text{C-F}} = 278.8$ Hz); ^{19}F NMR (376 MHz, CDCl_3) δ -79.2; HRMS (DART-TOF) m/z calcd for $\text{C}_7\text{H}_8\text{F}_6\text{O}_3$ $[\text{M} + \text{H}]^+$ 255.0456, found 255.0430.

Synthesis of 2-Cyano-1,3-dioxanes

Phthalimidoacetaldehyde diethyl acetal. Following the procedure of Anderson and coworkers¹⁴, with minor modifications, a mixture of 50.018 g (270 mmol) of potassium phthalimide, 45.0 mL (58.950 g, 299 mmol) of bromoacetaldehyde diethyl acetal, and 1.374 g (0.83 mmol) of potassium iodide in 300 mL of DMF was heated at 120 °C for 5 h. The solution was transferred to a separatory funnel and diluted with 200 mL of chloroform. The organic layer was washed with a 200 mL portion of water, two 350 mL portions of a 1M aqueous NaOH solution, two 250 mL portions of brine, dried over MgSO_4 , and concentrated under reduced pressure to yield 51.930 g of a crude brown oil. Purification of the title compound was accomplished by column chromatography (300 g SiO_2 , 0 \rightarrow 25% EtOAc/hexanes); 125 mL fractions were collected: 27.834 g of analytically pure title compound was collected in fractions 16–20; fractions 21–26 contained the title compound along with minor impurities, thus required recrystallization from warm EtOAc/hexanes to afford an additional 11.599 g of the analytically pure title compound. Progress of the chromatography was monitored by TLC (SiO_2 , eluent: 20% EtOAc in hexanes) and UV-light allowed for visualization of the title compound; $R_f = 0.39$. A combined total of 39.430 g (55%) of the title compound was isolated as a white, crystalline solid: mp 72.3–73.3 °C (EtOAc/hexanes) (lit.¹⁵ 72–73 °C); ^1H NMR (400 MHz, CDCl_3) δ 1.16 (t, $J = 7.1$ Hz, 6H), 3.54 (dq, $J = 9.4$ Hz, $J = 7.1$ Hz, 2H), 3.73 (dq, $J = 9.4$ Hz, $J = 7.1$ Hz, 2H), 3.83 (d, $J = 5.8$, 2H), 4.88 (t, $J = 5.8$ Hz, 1H), 7.71 (dd, $J = 5.6$ Hz, $J = 3.1$ Hz, 2H), 7.85 (dd, $J = 5.5$ Hz, $J = 3.1$ Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 15.5, 40.2, 62.1, 98.9, 123.6, 132.4, 134.3, 168.4.

N-Phthalimidyl-2-aminoacetaldehyde. Following the procedure of Banala and coworkers¹⁶, a solution of 22.960 g (87.2 mmol) of phthalimidoacetaldehyde diethyl acetal, 22 mL (132 mmol) of a 6M

aqueous HCl solution, and 175 mL of acetone was heated at reflux for 5 h. At which point, the solution was cooled to room temperature, transferred to a separatory funnel, and diluted with 200 mL of water. The solution was extracted with two 200-mL portions of EtOAc, the combined organic layers were dried (MgSO_4), and the solvent removed under reduced pressure to yield a crude brown solid which was recrystallized (CH_2Cl_2 /pentane) to afford 12.351 g (75%) of the title compound as an off-white, crystalline solid: mp 112–113 °C (sublimation) (lit.¹⁷ 114 °C); ^1H NMR (400 MHz, CDCl_3) δ 4.56 (s, 2H), 7.76 (dd, $J = 5.5$ Hz, $J = 3.1$ Hz, 2H), 7.89 (dd, $J = 5.4$ Hz, $J = 3.0$ Hz, 2H), 9.66 (s, 1H); ^{13}C NMR (100 MHz, CDCl_3) δ 47.6, 123.9, 132.2, 134.5, 167.7, 193.7.

***N*-((*cis*-4,*cis*-6-Dimethyl-1,3-dioxan-2-yl)-*r*-methyl)-phthalimide.** A mixture of 5.730 g (55.0 mmol) of *meso*-2,4-pentanediol, 10.000 g (52.8 mmol) of *N*-phthalimidyl-2-aminoacetaldehyde, 254 mg (1.33 mmol) of *p*-TsOH, and 250 mL of benzene was heated at reflux under a Dean-Stark trap for 8 h. At which point, the mixture was allowed to cool to room temperature, transferred to a separatory funnel, washed with two 100-mL portions of a saturated, aqueous Na_2CO_3 solution, one 150-mL portion of brine, the organic layer was dried over Na_2SO_4 , and solvent was removed under reduced pressure to give a crude brown solid. Recrystallization of the crude solid (CH_2Cl_2 /cyclohexane) yielded 12.667 g (88%) of the title compound as a white, crystalline solid: mp 173.8–174.2 °C (CH_2Cl_2 /cyclohexane); ^1H NMR (400 MHz, CDCl_3) δ 1.18 (d, $J = 6.2$ Hz, 6H), 1.29 (dt, $J = 13.1$ Hz, $J = 11.2$ Hz, 1H), 1.49 (dt, $J = 13.1$ Hz, $J = 2.4$ Hz, 1H), 3.68 (dq, $J = 11.1$ Hz, $J = 6.1$ Hz, $J = 2.3$ Hz, 2H), 3.85 (d, $J = 5.4$ Hz, 2H), 4.88 (t, $J = 5.4$ Hz, 1H), 7.71 (dd, $J = 5.4$ Hz, $J = 3.1$ Hz, 2H), 7.86 (dd, $J = 5.4$ Hz, $J = 3.1$ Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 21.6, 40.4, 41.5, 72.7, 97.2, 123.5, 132.4, 134.1, 168.2; HRMS (DART-TOF) m/z calcd for $\text{C}_{15}\text{H}_{17}\text{NO}_4$ [$\text{M} + \text{H}$]⁺ 276.1236, found 276.1232.

(*cis*-4,*cis*-6-Dimethyl-1,3-dioxan-2-yl)-*r*-methanamine. Employing the general procedure of Balenovic and coworkers¹⁸ with modifications, a mixture of 12.667 g (46.4 mmol) of *N*-((*cis*-4,*cis*-6-dimethyl-1,3-dioxan-2-yl)-*r*-methyl)-phthalimide, 3.60 mL (2.375 g, 47.4 mmol) of hydrazine hydrate (64 wt% hydrazine), and 170 mL of EtOH was refluxed for 5 h then allowed to cool to room temperature, at

which point a white precipitate of 2,3-dihydro-1,4-phthalazine formed. The mixture was then filtered through a bed of Celite, rinsing with a 100 mL portion of CH₂Cl₂ to remove the white solid, and the filtrate was then concentrated under reduced pressure to give a brown oil. The oil was triturated with 100 mL of cold CH₂Cl₂ to further precipitate the byproduct, filtered a second time through a bed of Celite rinsing with a cold CH₂Cl₂, and the solvent was removed under reduced pressure to afford a light orange oil. The crude oil was distilled (Kugelrohr, bath temperature = 85–90 °C, 40 mm) to yield 4.915 g (74%) of the title compound as a clear, colorless oil: $n_D^{22} = 1.4445$; ¹H NMR (400 MHz, CDCl₃) δ 1.22 (d, $J = 6.2$ Hz, 6H), 1.24 (dt, $J = 13.0$ Hz, $J = 11.1$ Hz, 1H), 1.30 (br s, 2H), 1.52 (dt, $J = 13.2$ Hz, $J = 2.4$ Hz, 1H), 2.80 (d, $J = 4.5$ Hz, 2H), 3.75 (dq, $J = 11.1$ Hz, $J = 6.2$ Hz, $J = 2.3$ Hz, 2H), 4.52 (t, $J = 4.5$ Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 21.7, 40.7, 46.0, 72.5, 101.7; HRMS (DART-TOF) m/z calcd for C₇H₁₅NO₂ [M + H]⁺ 146.1181, found 146.1180, m/z calcd for C₇H₁₅NO₂ [2M + H]⁺ 291.2284, found 291.2290.

***r*-2-Cyano-*cis*-4,*cis*-6-dimethyl-1,3-dioxane (10).** Following the conditions of our previously reported procedure, a slurry of 15.995 g (26.0 mmol) of Oxone[®], 72 mg (0.45 mmol) of pyridinium bromide, and 100 mL of CH₂Cl₂ was stirred for 15 min. until the solution developed a light yellow color. Then, 4.764 g (60.2 mmol) of dry pyridine was added, the mixture was stirred for 10 min. before the addition of 110 mg (0.52 mmol) of the 4-acetamido-2,2,6,6-tetramethylpiperidine-1-oxyl catalyst, and then stirred for an additional 15 min. until the solution returned to a light yellow color. Next, 1.453 g (10.1 mmol) of (*cis*-4,*cis*-6-dimethyl-1,3-dioxan-2-yl)-*r*-methanamine was dissolved in 20 mL of CH₂Cl₂, then added via syringe pump to the slurry at a rate of 10 mL/h and the reaction mixture was allowed to stir for 12 h at room temperature. At which point, the reaction mixture was filtered through a short plug of silica gel (~ 50 g) while rinsing with 150 mL of CH₂Cl₂. The filtrate was concentrated under reduced pressure to give 1.307 g of a light yellow oil, which was distilled (Kugelrohr, bath temperature = 80–100 °C, 10 mm) to yield 1.159 g (82%) of the title compound as a clear, colorless oil: $n_D^{23} = 1.4285$; ¹H NMR (400 MHz, CDCl₃) δ 1.27 (d, $J = 6.2$ Hz, 6H), 1.41 (dt, $J = 13.5$ Hz, $J = 11.1$ Hz, 1H), 1.58 (dt, $J = 13.5$

Hz, $J = 2.4$ Hz, 1H), 3.81 (dq, $J = 11.1$ Hz, $J = 6.2$ Hz, $J = 2.4$ Hz, 2H), 5.33 (s, 1H); ^{13}C NMR (100 MHz, CDCl_3) δ 21.3, 39.9, 74.3, 88.6, 114.7; HRMS (DART-TOF) m/z calcd for $\text{C}_7\text{H}_{11}\text{NO}_2$ $[\text{M} - \text{H}]^+$ 140.0712, found 140.0712, m/z calcd for $\text{C}_7\text{H}_{11}\text{NO}_2$ $[\text{M} + \text{NH}_4]^+$ 159.1134, found 159.1138.

***r*-2-Cyano-*trans*-4,*trans*-6-dimethyl-1,3-dioxane (9).** To an oven-dried, argon-flushed 5-mL vial was added 417 mg (2.96 mmol) of *r*-2-cyano-*cis*-4,*cis*-6-dimethyl-1,3-dioxane (**10**), 4.5 mL of pentane, 61 mg (0.54 mmol) of solid potassium *tert*-butoxide, and a small magnetic stir bar. The vial was tightly sealed with a Teflon-coated cap and allowed to stir for 24 h, at which point, it was opened and the contents were transferred by pipette and filtered through a bed of Celite into a 5-mL vial. The solution was concentrated to ~ 0.3 mL with a gentle stream of N_2 gas. Compound **9** was isolated from the concentrated solution by preparative TLC on a 1000 μm SiO_2 glass-backed plate using a 10% solution of Et_2O in hexanes as eluent to give a clear oil, which crystallized upon cooling to 0°C , to afford 100 mg (ca. 24%) of the title compound ($R_f = 0.47\text{--}0.54$) as a crystalline, white solid: mp $27.8 - 28.9^\circ\text{C}$ (Et_2O /pentane); ^1H NMR (400 MHz, CDCl_3) δ 1.26 (d, $J = 6.2$ Hz, 6H), 1.40 (dt, $J = 13.5$ Hz, $J = 11.3$ Hz, 1H), 1.66 (dt, $J = 13.6$ Hz, $J = 2.0$ Hz, 1H), 4.18 (dq, $J = 11.3$ Hz, $J = 6.1$ Hz, $J = 2.3$ Hz, 2H), 5.74 (s, 1H); ^{13}C NMR (100 MHz, CDCl_3) δ 21.3, 39.9, 69.2, 87.4, 114.7; HRMS (DART-TOF) m/z calcd for $\text{C}_7\text{H}_{11}\text{NO}_2$ $[\text{M} + \text{NH}_4]^+$ 159.1134, found 159.1130.

***N*-((*cis*-4,*cis*-6-Bis(trifluoromethyl)-1,3-dioxan-2-yl)-*r*-methyl)-phthalimide.** A mixture of 3.679 g (17.3 mmol) of *meso*-1,1,1,5,5,5-hexafluoro-2,4-pentanediol, 4.572 g (17.3 mmol) of phthalimidoacetaldehyde diethyl acetal, 239 mg (1.26 mmol) of *p*-TsOH, and 150 mL of hexanes was heated at reflux under a Dean-Stark trap for 24 h and the reaction mixture was then allowed to cool to room temperature. Upon cooling, a light brown solid precipitated. The reaction mixture was then transferred to a separatory funnel, diluted with 200 mL of CH_2Cl_2 , and the organic layer was rinsed with two 100-mL portions of a saturated, aqueous Na_2CO_3 solution, dried over Na_2SO_4 , and solvent removed under reduced pressure to afford a brown solid. The crude material was dissolved in 100 mL of EtOAc and adsorbed onto 10 g of SiO_2 for flash chromatography. Separation of the title compound was achieved

by “double” flash column chromatography (200 g SiO₂, 30 → 50% EtOAc/hexanes); 50 mL fractions were collected: 3.469 g (52%) of the title compound of ~ 90% purity was collected in fractions 7–16. This almost pure material was dissolved in 100 mL of EtOAc and was adsorbed onto 8.5 g of SiO₂ for additional chromatography (150 g SiO₂, 30 → 70% Et₂O/hexanes); 50 mL fractions were collected: 3.036 g (46%) of the title compound was collected in fractions 16–26. Progress of the chromatography was monitored by TLC (SiO₂, eluent: 50% Et₂O in hexanes) and UV-light allowed for visualization of the title compound. The starting material had an R_f = 0.64 and the title compound had an R_f = 0.43: white, crystalline solid; mp 196.1–197.0 °C (Et₂O/hexanes); ¹H NMR (400 MHz, CDCl₃) δ 1.88 (dt, J = 13.0 Hz, J = 2.6 Hz, 1H), 2.00 (dt, J = 12.8 Hz, J = 11.8, 1H), 4.00 (d, J = 5.3 Hz, 2H), 4.12 (dq, J = 11.6 Hz, J = 5.6 Hz, J = 2.9 Hz, 2H), 5.08 (t, J = 5.4 Hz, 2H), 7.74 (dd, J = 5.4 Hz, J = 3.0, 2H), 7.87 (dd, J = 5.4 Hz, J = 3.0, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 22.8, 40.4, 73.1 (quartet, J_{C-F} = 34.1 Hz), 97.4, 122.8 (quartet, J_{C-F} = 278.9 Hz), 123.8, 132.0, 134.4, 167.9; ¹⁹F NMR (376 MHz, CDCl₃) δ -79.4; HRMS (DART-TOF) m/z calcd for C₁₅H₁₁F₆NO₄ [M + H]⁺ 384.0671, found 384.0645.

(*cis*-4,*cis*-6-Bis(trifluoromethyl)-1,3-dioxan-2-yl)-*r*-methanamine. A mixture of 2.756 g (7.19 mmol) of *N*-((*cis*-4,*cis*-6-bis(trifluoromethyl)-1,3-dioxan-2-yl)-*r*-methyl)-phthalimide, 0.850 mL (528 mg, 10.5 mmol) of hydrazine hydrate (64 wt% hydrazine), and 100 mL of EtOH was heated at reflux for 5 h then allowed to cool to room temperature, at which point a white precipitate of 2,3-dihydro-1,4-phthalazine formed. An additional 100 mL of a 2:1 mixture of pentane/CH₂Cl₂ was added to the flask, which was then cooled to 0 °C in an ice/water bath to further precipitate the white solid. The mixture was filtered through a bed of Celite to remove the white solid. The filtrate was then concentrated under reduced pressure resulting in further precipitation of the byproduct, filtered a second time through a bed of Celite rinsing with a cold 2:1 mixture of pentane/CH₂Cl₂, and the solvent was removed under reduced pressure to afford a light yellow oil. The crude oil was distilled (Kugelrohr, bath temperature = 120–130 °C, 40 mm) to yield 1.402 g (77%) of the title compound as a crystalline, white solid: mp 36.4–37.2 °C (sublimation); ¹H NMR (400 MHz, CDCl₃) δ 1.30 (br s, 2H), 1.85–2.00 (m, 2H), 2.94 (d, J = 4.1 Hz, 2H),

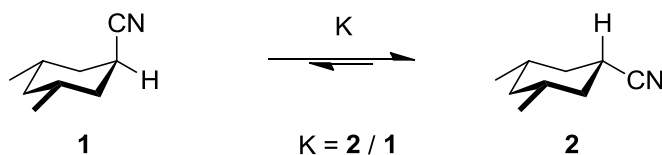
4.11–4.20 (m, 2H), 4.65 (t, $J = 4.1$ Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 22.9, 45.2, 73.0 (quartet, $J_{\text{C-F}} = 34.0$ Hz), 102.0, 123.0 (quartet, $J_{\text{C-F}} = 279.0$ Hz); ^{19}F NMR (376 MHz, CDCl_3) δ -79.5; HRMS (DART-TOF) m/z calcd for $\text{C}_7\text{H}_9\text{F}_6\text{NO}_2$ $[\text{M} + \text{H}]^+$ 254.0615, found 254.0603.

***r*-2-Cyano-*cis*-4,*cis*-6-bis(trifluoromethyl)-1,3-dioxane (12).** Following the conditions of our previously reported procedure,¹⁹ a slurry of 16.010 g (26.1 mmol) of Oxone®, 71 mg (0.44 mmol) of pyridinium bromide, and 100 mL of CH_2Cl_2 was stirred for 15 min. until the solution developed a light yellow color. Then, 4.754 g (60.1 mmol) of dry pyridine was added, the mixture was stirred for 10 min before the addition of 108 mg (0.51 mmol) of the 4-acetamido-2,2,6,6-tetramethylpiperidine-1-oxyl catalyst, and then stirred for an additional 15 min. until the solution returned to a light yellow color. Next, 582 mg (2.30 mmol) of (*cis*-4,*cis*-6-bis(trifluoromethyl)-1,3-dioxan-2-yl)-*r*-methanamine was dissolved in 20 mL of CH_2Cl_2 , then added via syringe pump to the slurry at a rate of 10 mL/h and following the addition, the reaction mixture was allowed to stir for 12 h at room temperature. The reaction mixture was filtered through a short plug of SiO_2 (~ 50 g) while rinsing with 150 mL of CH_2Cl_2 . The filtrate was concentrated under reduced pressure to yield a clear oil, which was triturated with pentane. Upon removal of the solvent 550 mg (96%) of the title compound was isolated as a white solid: mp 30.1–30.8 °C (pentane); ^1H NMR (400 MHz, CDCl_3) δ 2.00 (dt, $J = 13.3$ Hz, $J = 2.7$ Hz, 1H), 1.98 (dt, $J = 13.3$ Hz, $J = 11.8$, 1H), 4.26 (dq, $J = 11.6$ Hz, $J = 5.4$ Hz, $J = 2.7$ Hz, 2H), 5.47 (s, 1H); ^{13}C NMR (100 MHz, CDCl_3) δ 22.5, 73.5 (quartet, $J_{\text{C-F}} = 35.5$ Hz), 87.9, 112.0, 122.1 (quartet, $J_{\text{C-F}} = 278.6$ Hz); ^{19}F NMR (376 MHz, CDCl_3) δ -79.1; HRMS (DART-TOF) m/z calcd for $\text{C}_7\text{H}_5\text{F}_6\text{NO}_2$ $[\text{M} - \text{HCN}]^+$ 223.0194, found 223.0217.

***r*-2-Cyano-*trans*-4,*trans*-6-bis(trifluoromethyl)-1,3-dioxane (11).** To an oven-dried, argon-flushed 2-mL amber vial was added 68 mg (0.273 mmol) of *r*-2-cyano-*cis*-4,*cis*-6-bis(trifluoromethyl)-1,3-dioxane (**12**), 1.5 mL of Et_2O , 11 mg (0.10 mmol) of solid potassium *tert*-butoxide, and a small magnetic stir bar. The vial was carefully flame-sealed and stirred for 24 h, at which point, it was opened and the contents were transferred by pipette into a 3-mL vial containing 1 mL of a saturated, aqueous

NH₄Cl solution and shaken. The top organic layer was carefully separated from the aqueous layer by pipette, transferred into a separate vial, and the solution was concentrated to ~ 0.3 mL with a gentle stream of N₂ gas. Compound **11** was isolated from the concentrated solution by preparative TLC on a 1000 μ m SiO₂ glass-backed plate using a 10% solution of Et₂O in pentane as eluent to afford 32 mg (ca. 47%) of the title compound (*R*_f = 0.58–0.78) as a crystalline, white solid: mp 33.1–33.7 °C (Et₂O); ¹H NMR (400 MHz, CDCl₃) δ 2.04–2.19 (m, 2H), 4.50–4.60 (m, 2H), 5.97 (s, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 22.5, 69.9 (quartet, *J*_{C–F} = 35.5 Hz), 86.4, 111.8, 122.4 (quartet, *J*_{C–F} = 279.1 Hz); ¹⁹F NMR (376 MHz, CDCl₃) δ –79.2; HRMS (DART-TOF) *m/z* calcd for C₇H₅F₆NO₂ [M – HCN]⁺ 223.0194, found 223.0187.

Gas Chromatography Parameters, Representative Chromatograms and Equilibration Data

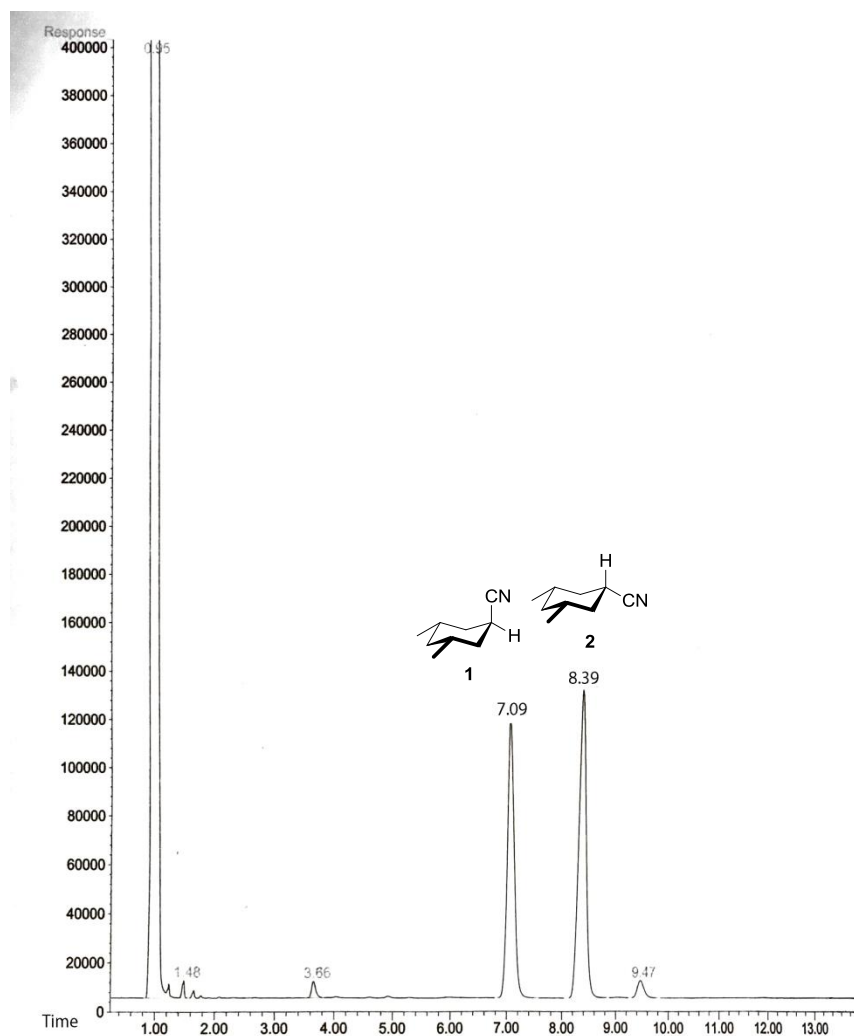


GC column: Optima[®] 225; 50% cyanopropyl, 50% phenylmethyl polysiloxane; 30 meters; id- 0.25 mm; film- 0.25 μm

Program Description:

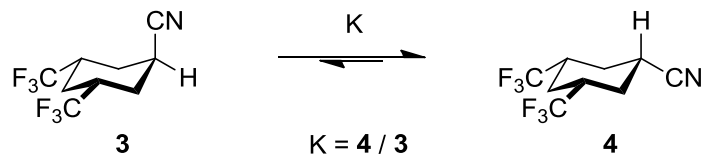
The initial temperature was set at 100 °C for five minutes and increased at a rate of 2 °C/min and held at a final temperature of 170 °C for a period of 10 min.

Compound	Ret. Time
1	7.09 min
2	8.39 min



<div><div><div><div><div><div></div><div>CN</div></div><div><div></div><div>H</div></div></div><div></div><div><div></div><div></div></div></div><div></div><div>K</div><div><div><div></div><div>H</div></div><div><div></div><div>CN</div></div></div><div></div></div><div>1</div><div>K = 2 / 1</div><div>2</div></div>									
Equilibrium study from <i>trans</i> -3, <i>trans</i> -5-dimethylcarbonitrile (1) in THF									
Area of axial cyano isomer (1)	Area of equatorial cyano isomer (2)	K	K _{AV}	Overall \bar{K}	$(K - \bar{K})^2$	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
8960735	13290620	1.48320646	1.47890371	1.48462	2.00727E-06	0.00186	0.002616343	-0.23256378	-0.233 +/- 0.001 kcal/mol
7854488	11518458	1.46648107			0.000329138			-0.23360003	-0.001036249
11904095	17690502	1.48608542			2.13797E-06			-0.23152571	-0.001038076
10868186	15987370	1.4710247			0.00018492				
9731718	14302148	1.46964267			0.000224417				
8195084	12123535	1.47936678			2.76304E-05				
16324720	24550623	1.50389244			0.000371302				
8872499	13073948	1.47353615			0.000122924				
6765314	9991677	1.47689775			5.96832E-05				
Equilibrium study from <i>cis</i> -3, <i>cis</i> -5-dimethylcarbonitrile (2) in THF									
Area of axial cyano isomer (1)	Area of equatorial cyano isomer (2)	K	K _{AV}		$(K - \bar{K})^2$				
4491408	6675109	1.4861952	1.49197691		2.47106E-06				
5988576	8965392	1.49708244			0.000155232				
6560688	9734274	1.48372762			8.02128E-07				
14462493	21595797	1.49322783			7.4039E-05				
15620419	23379558	1.49673053			0.000146587				
13071530	19504878	1.49216488			5.68764E-05				
7200052	10629231	1.47627142			6.97528E-05				
11257382	16826520	1.49470987			0.00010174				
Equilibrium study from <i>trans</i> -3, <i>trans</i> -5-dimethylcarbonitrile (1) in ether									
Area of axial cyano isomer (1)	Area of equatorial cyano isomer (2)	K	K _{AV}	Overall \bar{K}	$(K - \bar{K})^2$	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
44616089	62149084	1.39297472	1.37512787	1.35925	0.001137027	0.03406	0.011190993	-0.18064118	-0.181 +/- 0.005 kcal/mol
3274935	4072077	1.24340697			0.013420742			-0.18546681	-0.00482563
69616056	96347880	1.38398935			0.000611793			-0.17577566	-0.004865525
77331391	110936955	1.43456562			0.005671706				
27874759	38245009	1.37203012			0.000163206				
30980292	42506477	1.37204895			0.000163688				
36217815	49793534	1.3748354			0.000242752				
31495680	43208474	1.37188573			0.000159538				
61972919	88646927	1.43041394			0.005063609				
Equilibrium study from <i>cis</i> -3, <i>cis</i> -5-dimethylcarbonitrile (2) in ether									
Area of axial cyano isomer (1)	Area of equatorial cyano isomer (2)	K	K _{AV}		$(K - \bar{K})^2$				
163211498	221950059	1.3598923	1.3413978		4.06283E-07				
204482735	278114263	1.36008677			6.92021E-07				
11450764	14846952	1.29659052			0.003926824				
50703503	68811427	1.35713359			4.49994E-06				
31240281	40668340	1.30179175			0.003302013				
135807189	183925966	1.35431686			2.43842E-05				
104796319	141175839	1.34714502			0.000146649				
153365621	207691652	1.35422561			2.52937E-05				

Equilibrium study from <i>trans</i> -3, <i>trans</i> -5-dimethylcarbonitrile (1) in cyclohexane									
Area of axial cyano isomer (1)	Area of equatorial cyano isomer (2)	K	K _{Av}	Overall K	(K - \bar{K}) ²	$\Sigma(K - \bar{K})^2$	S _m = 1/[n(n-1)] ^{1/2} $\Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
42872250	53208121	1.24108534	1.22546364	1.22283	0.000333309	0.00099	0.001460929	-0.11839246	-0.118+/-0.001 kcal/mol
42659014	52258191	1.22502107			4.80699E-06			-0.11909516	-0.000702704
27414478	33712579	1.22973631			4.77166E-05			-0.11768892	-0.000703544
44833830	55343152	1.23440607			0.000134038				
46827517	57354230	1.22479759			3.87698E-06				
32400708	39653446	1.22384505			1.03319E-06				
28899171	35512977	1.22885798			3.63536E-05				
23367727	28497183	1.21951027			1.10112E-05				
50075552	61271726	1.22358563			5.73121E-07				
40866938	49794357	1.21845089			1.91642E-05				
24934681	30594399	1.22698177			1.72489E-05				
46539702	56279797	1.20928572			0.000183409				
Equilibrium study from <i>cis</i> -3, <i>cis</i> -5-dimethylcarbonitrile (2) in cyclohexane									
Area of axial cyano isomer (1)	Area of equatorial cyano isomer (2)	K	K _{Av}		(K - \bar{K}) ²				
14355156	17493307	1.21860793	1.21966652		1.78139E-05				
14402963	17578467	1.22047575			5.53586E-06				
22473746	27464219	1.22205791			5.93945E-07				
24523391	30022404	1.22423542			1.9792E-06				
14402963	17578467	1.22047575			5.53586E-06				
11739051	14278703	1.21634219			4.20733E-05				
25863011	31657284	1.22403706			1.46042E-06				
15459008	18828343	1.21795286			2.37727E-05				
11962787	14525799	1.21424874			7.36138E-05				
9916603	12080719	1.21823159			2.11324E-05				

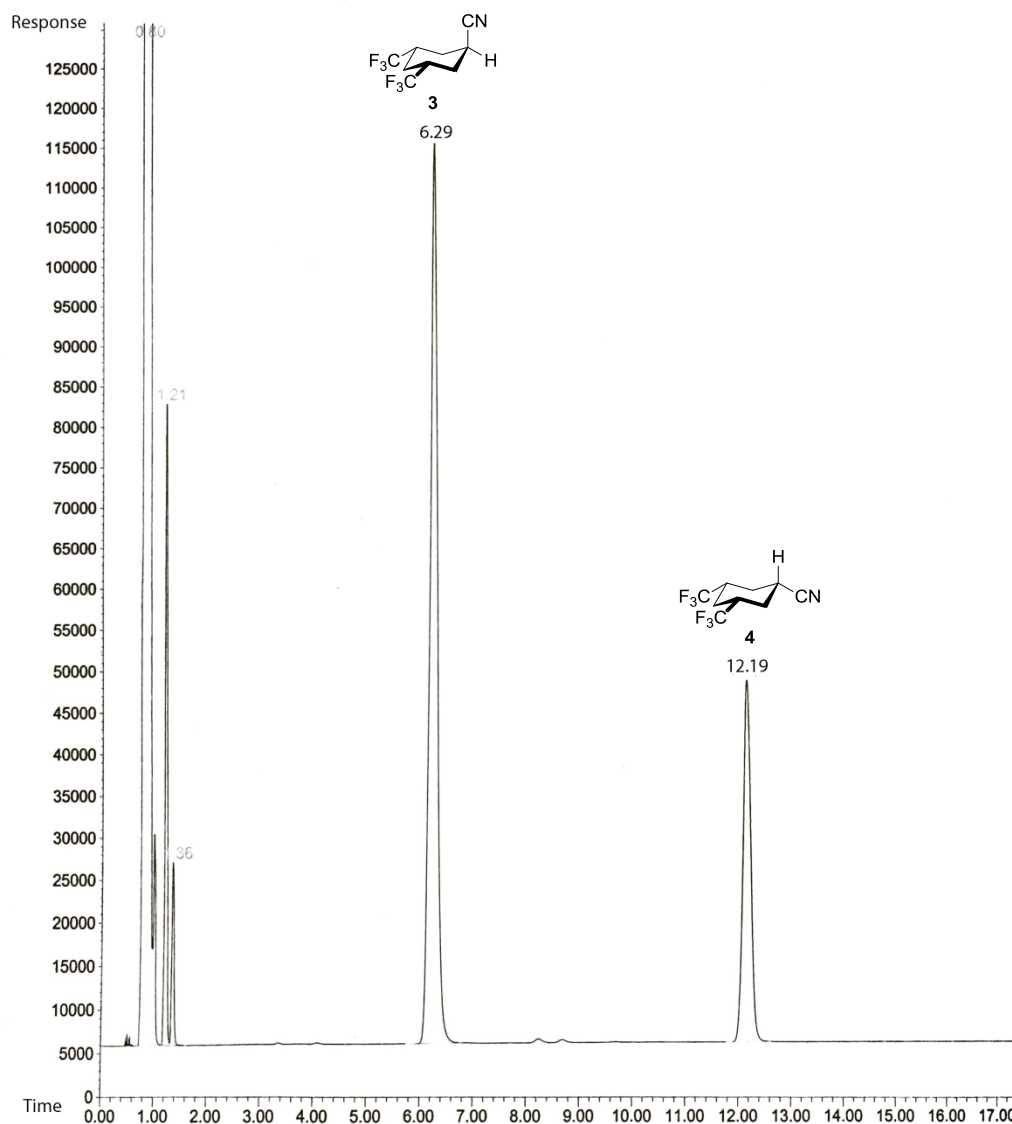


GC column: Optima[®] 225; 50% cyanopropyl, 50% phenylmethyl polysiloxane; 30 meters; id- 0.25 mm; film- 0.25 μ m

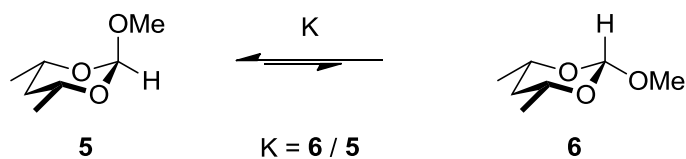
Program Description:

The initial temperature was set at 100 °C for five minutes and increased at a rate of 3 °C/min and held at a final temperature of 230 °C for a period of 20 min.

Compound	Ret. Time
3	6.29 min
4	12.19 min



Equilibrium study from <i>trans</i> -3, <i>trans</i> -5-Bis(trifluoromethyl)cyclohexanecarbonitrile (3) in cyclohexane									
Area of axial cyano isomer (3)	Area of equatorial cyano isomer (4)	K	K _{Av}	Overall R	(K - \bar{K}) ²	$\Sigma(K - \bar{K})^2$	S _m = 1/[n(n-1)] ^{1/2} $\Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
8698310	3862793	0.44408546	0.44469098	0.44234	3.03451E-06	0.00042	0.000952518	0.48004475	0.480 +/- 0.001 kcal/mol
8760508	3885366	0.44350921			1.35894E-06			0.47877881	-0.001265943
9169243	4063503	0.44316668			6.77667E-07			0.48131342	-0.001268672
10659800	4787157	0.44908507			4.5449E-05				
10459810	4699067	0.44924975			4.76966E-05				
11603298	5071365	0.43706238			2.789E-05				
9410661	4182536	0.44444657			4.423E-06				
11618016	5172289	0.44519555			8.13431E-06				
11703863	5237574	0.44750814			2.66738E-05				
12242258	5430678	0.44360101			1.58139E-06				
Equilibrium study from <i>cis</i> -3, <i>cis</i> -5-Bis(trifluoromethyl)cyclohexanecarbonitrile (4) in cyclohexane									
Area of axial cyano isomer (3)	Area of equatorial cyano isomer (4)	K	K _{Av}		(K - \bar{K}) ²				
9106073	3993648	0.43856973	0.43999597		1.42411E-05				
10837890	4676285	0.43147559			0.000118111				
12206758	5335647	0.43710599			2.74313E-05				
8012599	3580006	0.4467971			1.98348E-05				
12171893	5339339	0.43866135			1.35581E-05				
11306235	4986290	0.44102126			1.74826E-06				
10403871	4532592	0.43566399			4.46155E-05				
9786329	4345591	0.4440471			2.90233E-06				
10806554	4812176	0.44530162			8.75061E-06				
10677619	4712204	0.44131599			1.05573E-06				

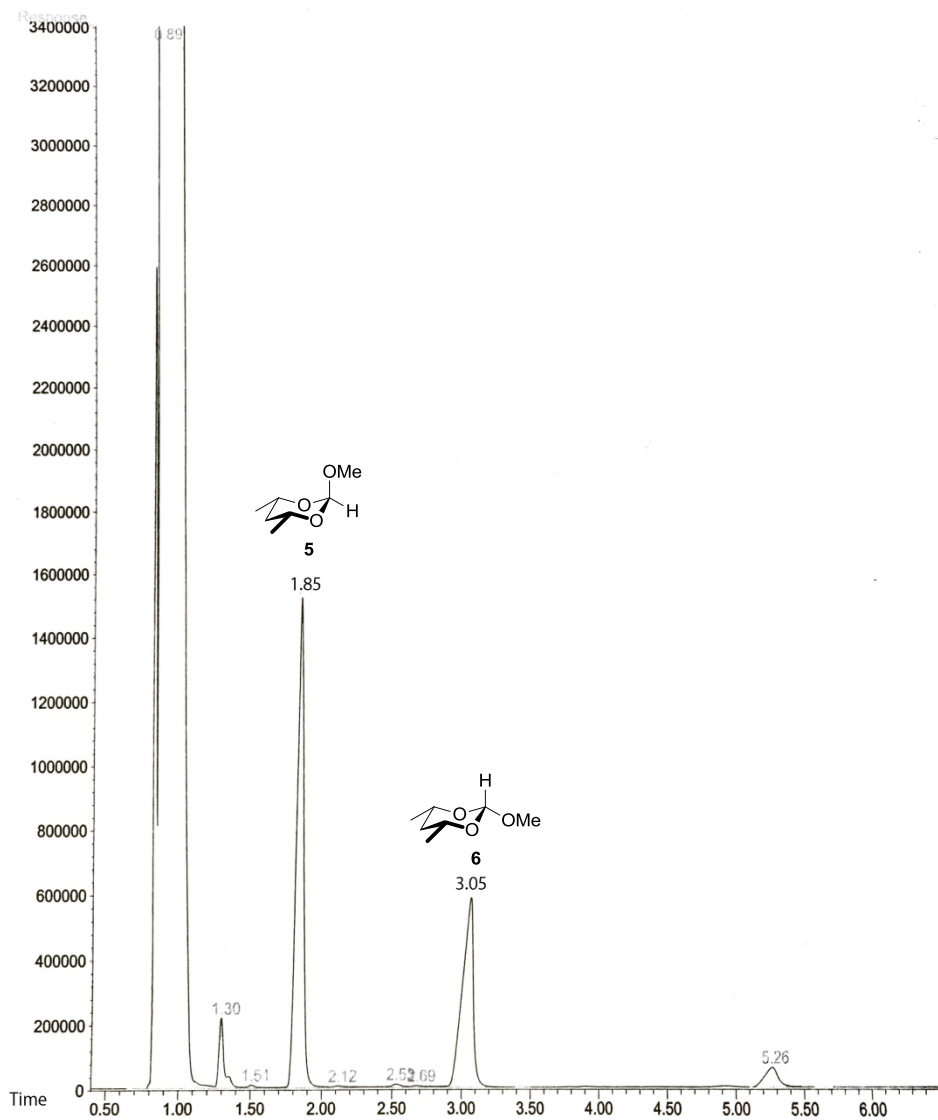


GC column: Optima[®] 225; 50% cyanopropyl, 50% phenylmethyl polysiloxane; 30 meters; id- 0.25 mm; film- 0.25 μ m

Program Description:

The initial temperature was set at 100 °C for five minutes and increased at a rate of 3 °C/min and held at a final temperature of 230 °C for a period of 20 min.

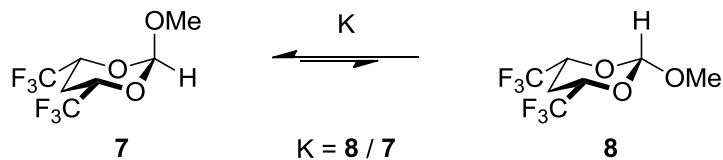
Compound	Ret. Time
5	1.85 min
6	3.05 min



<div style="text-align: center;"> <p>5 \xrightleftharpoons{K} 6 K = 6 / 5</p> </div>									
Equilibrium study from <i>r</i> -2-Methoxy- <i>trans</i> -4, <i>trans</i> -6-dimethyl-1,3-dioxane (5) in acetonitrile									
Area of axial methoxy isomer (5)	Area of equatorial Methoxy isomer (6)	K	K _{Av}	Overall K	(K - \bar{K}) ²	$\Sigma(K - \bar{K})^2$	S _m = 1/[n(n-1)] ^{1/2} $\Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
86104498	91795704	1.0660965	1.07454183	1.07505	8.02505E-05	0.00066	0.001315537	-0.0425928	-0.042 +/- 0.001 kcal/mol
114878469	123317874	1.07346377			2.53127E-06			-0.04331254	-0.000719739
54391379	58683739	1.07891618			1.49106E-05			-0.04187218	-0.00072062
56720056	60573542	1.06793868			5.06386E-05				
81982196	87923519	1.07247089			6.67638E-06				
30112682	32471052	1.07831817			1.06498E-05				
76013799	82015908	1.07896078			1.5257E-05				
90935151	97394878	1.07103663			1.61454E-05				
105526721	113731192	1.07774781			7.25248E-06				
47150028	50944138	1.08046888			2.93127E-05				
Equilibrium study from <i>r</i> -2-Methoxy- <i>cis</i> -4, <i>cis</i> -6-dimethyl-1,3-dioxane (6) in acetonitrile									
Area of axial methoxy isomer (5)	Area of equatorial Methoxy isomer (6)	K	K _{Av}		(K - \bar{K}) ²				
64358294	68602254	1.06594271	1.07556769		8.30296E-05				
45000498	48852606	1.08560145			0.000111233				
30996485	33163591	1.06991457			2.64215E-05				
50947700	55096885	1.08144008			4.07723E-05				
45209249	48832925	1.08015342			2.59963E-05				
39418470	42269358	1.07232366			7.45892E-06				
83696743	89285003	1.06676795			6.86712E-05				
52013104	56014397	1.07692856			3.5111E-06				
67992233	73028388	1.07406956			9.70617E-07				
56792015	61479343	1.08253498			5.59537E-05				
Equilibrium study from <i>r</i> -2-Methoxy- <i>trans</i> -4, <i>trans</i> -6-dimethyl-1,3-dioxane (5) in THF									
Area of axial methoxy isomer (5)	Area of equatorial Methoxy isomer (6)	K	K _{Av}	Overall K	(K - \bar{K}) ²	$\Sigma(K - \bar{K})^2$	S _m = 1/[n(n-1)] ^{1/2} $\Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
55145426	35645976	0.6463995	0.64661058	0.64344	8.73306E-06	0.00087	0.001517153	0.25949414	0.259 +/- 0.001 kcal/mol
63708838	41346134	0.64898584			3.07084E-05			0.2581081	-0.001386037
56693262	36703007	0.64739628			1.56179E-05			0.26088345	-0.001389309
60185735	38642802	0.64205915			1.91871E-06				
89643657	58057942	0.64765254			1.7709E-05				
72380573	46967874	0.64890166			2.97825E-05				
80934355	52567241	0.64950466			3.67277E-05				
87511877	56304623	0.64339407			2.52558E-09				
60580476	39192267	0.64694551			1.22583E-05				
59660137	38472826	0.64486654			2.02268E-06				
Equilibrium study from <i>r</i> -2-Methoxy- <i>cis</i> -4, <i>cis</i> -6-dimethyl-1,3-dioxane (6) in THF									
Area of axial methoxy isomer (5)	Area of equatorial Methoxy isomer (6)	K	K _{Av}		(K - \bar{K}) ²				
32869781	21066057	0.64089435	0.64027808		6.50238E-06				
31582891	20470360	0.64814712			2.21163E-05				
29828136	19270931	0.64606555			6.87079E-06				
28993702	18390331	0.63428709			8.38549E-05				
40474981	26136542	0.64574563			5.29598E-06				
45726608	29212245	0.63884566			2.11478E-05				
46837402	30051905	0.64162195			3.32108E-06				
47983520	31012450	0.64631461			8.23851E-06				
46758139	29971511	0.64099025			6.02252E-06				
52010265	32239530	0.6198686			0.000555815				

Equilibrium study from <i>r</i> -2-Methoxy- <i>trans</i> -4, <i>trans</i> -6-dimethyl-1,3-dioxane (5) in ether									
Area of axial methoxy isomer (5)	Area of equatorial Methoxy isomer (6)	K	K _{Av}	Overall \bar{K}	$(K - \bar{K})^2$	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
94683096	49231914	0.51996519	0.51865212	0.50808	0.000141368	0.00247	0.002547634	0.39850808	0.399 +/- 0.003 kcal/mol
112964397	58960993	0.52194315			0.000192315			0.3955644	-0.002943679
104065602	54656373	0.52521075			0.000293621			0.40146656	-0.002958476
193673325	101464373	0.52389441			0.000250242				
82883945	42671011	0.51482843			4.56037E-05				
113307064	58209652	0.51373365			3.20161E-05				
73482487	37661370	0.51252171			1.97699E-05				
109010305	56738644	0.52048881			0.000154093				
135916458	70460125	0.5184076			0.000106755				
141263302	72825113	0.51552747			5.55338E-05				
Equilibrium study from <i>r</i> -2-Methoxy- <i>cis</i> -4, <i>cis</i> -6-dimethyl-1,3-dioxane (6) in ether									
Area of axial methoxy isomer (5)	Area of equatorial Methoxy isomer (6)	K	K _{Av}		$(K - \bar{K})^2$				
55036827	27354745	0.4970262	0.49749863		0.000122084				
34497643	17068212	0.49476458			0.000177177				
38630971	19228436	0.49774664			0.000106683				
75832196	37530177	0.49491086			0.000173305				
77412071	38225141	0.49378786			0.000204133				
48774602	24312265	0.49846158			9.24251E-05				
41146547	20541581	0.49922977			7.82448E-05				
58441022	29349307	0.50220386			3.44746E-05				
70518828	35118628	0.49800357			0.000101441				
49506157	24696214	0.49885137			8.50823E-05				
Equilibrium study from <i>r</i> -2-Methoxy- <i>trans</i> -4, <i>trans</i> -6-dimethyl-1,3-dioxane (5) in cyclohexane									
Area of axial methoxy isomer (5)	Area of equatorial Methoxy isomer (6)	K	K _{Av}	Overall \bar{K}	$(K - \bar{K})^2$	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
38343045	15901245	0.41471002	0.42519034	0.42098	3.93096E-05	0.00119	0.001772969	0.50917808	0.509 +/- 0.002 kcal/mol
45634998	20037940	0.43909151			0.000328035			0.50670467	-0.002473403
53361578	22406643	0.41990218			1.16117E-06			0.51166192	-0.002483842
50936957	21383051	0.41979443			1.405E-06				
39780569	16764687	0.42142904			2.01853E-07				
49682480	21702351	0.43682101			0.000250945				
34768940	14561555	0.41880929			4.71095E-06				
27408387	11635557	0.42452542			1.25717E-05				
33886346	14443964	0.42624732			2.77471E-05				
18124142	7803770	0.43057321			9.20343E-05				
Equilibrium study from <i>r</i> -2-Methoxy- <i>cis</i> -4, <i>cis</i> -6-dimethyl-1,3-dioxane (6) in cyclohexane									
Area of axial methoxy isomer (5)	Area of equatorial Methoxy isomer (6)	K	K _{Av}		$(K - \bar{K})^2$				
28324383	11458810	0.40455639	0.41676918		0.000269727				
41705688	17331270	0.4155613			2.93597E-05				
24594600	10443117	0.42461016			1.31798E-05				
32893466	13852435	0.42113029			2.26607E-08				
26838650	11299493	0.4210157			1.29171E-09				
46604359	19279652	0.41368774			5.31735E-05				
47280415	19713737	0.41695355			1.62103E-05				
39157808	16319270	0.41675647			1.78361E-05				
45646402	19041870	0.41716037			1.45877E-05				
40271419	16763372	0.41625978			2.22782E-05				

Equilibrium study from <i>r</i> -2-Methoxy- <i>trans</i> -4, <i>trans</i> -6-dimethyl-1,3-dioxane (5) in pentane									
Area of axial methoxy isomer (5)	Area of equatorial Methoxy isomer (6)	K	K _{Av}	Overall R	(K - \bar{K}) ²	$\Sigma(K - \bar{K})^2$	S _m = 1/[n(n-1)] ^{1/2} $\Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
67118245	27042198	0.40290383	0.39822569	0.39882	1.67035E-05	0.0002	0.000732309	0.5410072	0.541+/-0.001 kcal/mol
23909898	9485015	0.39669826			4.48837E-06			0.53992753	-0.001079668
50500873	19771458	0.39150725			5.34301E-05			0.54208885	-0.001081653
34508164	13619415	0.39467226			1.71776E-05				
32650619	13184631	0.40380953			2.49269E-05				
35656585	14406174	0.40402562			2.71314E-05				
39610777	15749695	0.39761136			1.45318E-06				
52442151	20814944	0.39691248			3.6266E-06				
68793040	27082244	0.39367709			2.6417E-05				
41206721	16500785	0.40043917			2.63194E-06				
Equilibrium study from <i>r</i> -2-Methoxy- <i>cis</i> -4, <i>cis</i> -6-dimethyl-1,3-dioxane (6) in pentane									
Area of axial methoxy isomer (5)	Area of equatorial Methoxy isomer (6)	K	K _{Av}		(K - \bar{K}) ²				
50652754	20224527	0.39927793	0.399408		2.12608E-07				
41100939	16352899	0.39787166			8.93358E-07				
34794700	13949159	0.40089896			4.33522E-06				
38574079	15436749	0.40018451			1.87053E-06				
42435126	17036455	0.40147059			7.04238E-06				
50647216	20297261	0.40075768			3.76688E-06				
63763829	25338171	0.39737531			2.07802E-06				
39694903	15777821	0.39747725			1.79449E-06				
61070330	24313643	0.39812529			4.78238E-07				
45449799	18209042	0.40064076			3.32668E-06				

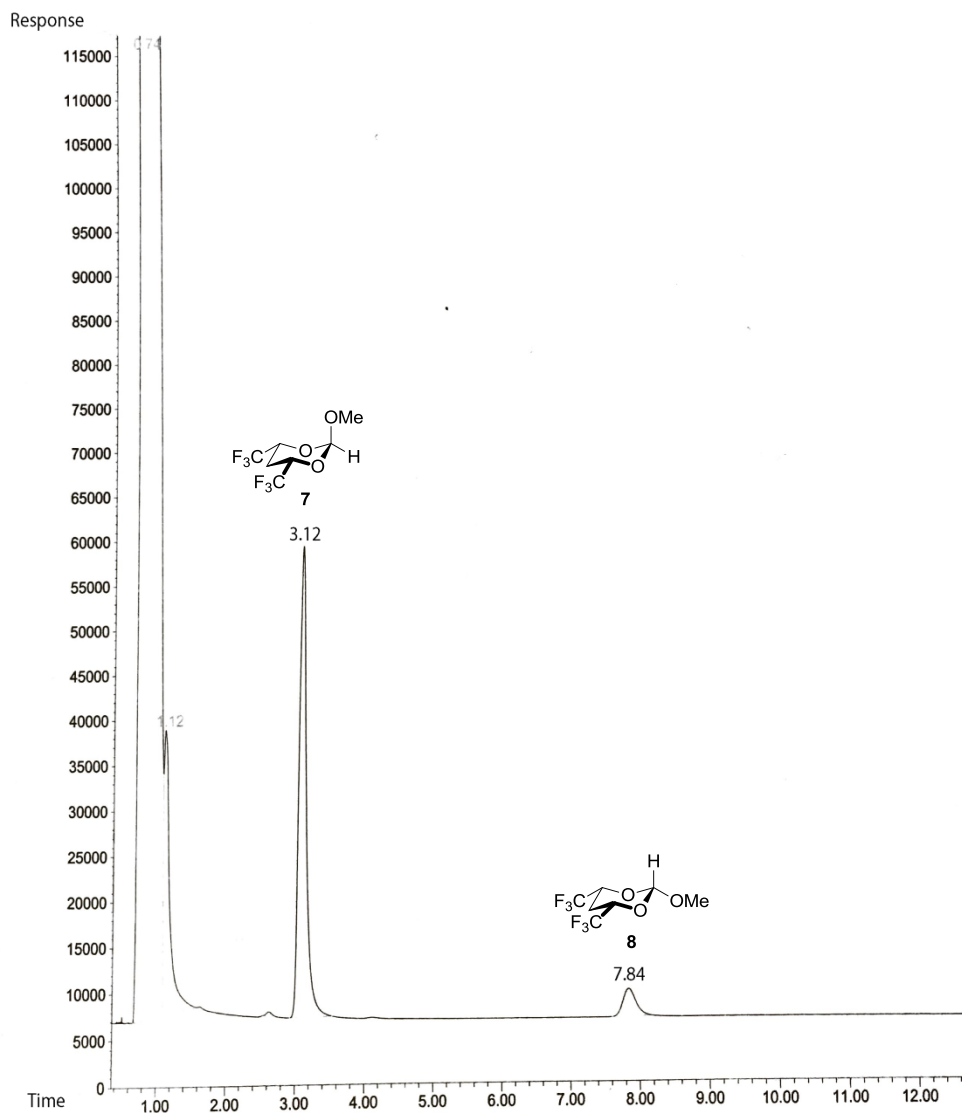


GC column: Optima[®] 225; 50% cyanopropyl, 50% phenylmethyl polysiloxane; 30 meters; id- 0.25 mm; film- 0.25 μ m

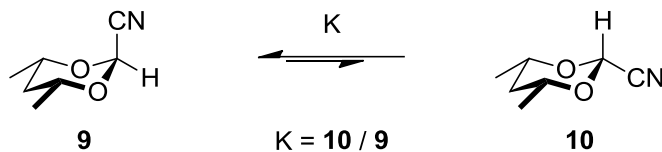
Program Description:

The initial temperature was set at 60 °C for five minutes and increased at a rate of 2 °C/min and held at a final temperature of 170 °C for a period of 10 min.

Compound	Ret. Time
7	3.12 min
8	7.84 min



Equilibrium study from <i>r</i> -2-Methoxy- <i>trans</i> -4, <i>trans</i> -6-bistrifluoromethyl-1,3-dioxane (7) in cyclohexane									
Area of axial methoxy isomer (7)	Area of equatorial Methoxy isomer (8)	K	K _{Av}	Overall R	(K - \bar{K}) ²	$\Sigma(K - \bar{K})^2$	S _m = 1/[n(n-1)] ^{1/2} $\Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
65501215	4571822	0.06979751	0.06885681	0.06887	8.6001E-07	0.0001	0.000518632	1.57462886	1.575+/-0.004 kcal/mol
35327732	2482107	0.07025945			1.93016E-06			1.57021349	-0.004415362
65999483	4446218	0.06736747			2.25805E-06			1.57907759	-0.004448738
55714655	3805672	0.06830648			3.1772E-07				
56969016	3854548	0.06766043			1.46342E-06				
55403137	3785132	0.06831981			3.02867E-07				
50913580	3535381	0.06943886			3.23435E-07				
57592781	3882530	0.06741348			2.12187E-06				
54150402	3790599	0.07000131			1.27953E-06				
50965955	3567787	0.07000334			1.28412E-06				
Equilibrium study from <i>r</i> -2-Methoxy- <i>cis</i> -4, <i>cis</i> -6-bistrifluoromethyl-1,3-dioxane (8) in cyclohexane									
Area of axial methoxy isomer (7)	Area of equatorial Methoxy isomer (8)	K	K _{Av}		(K - \bar{K}) ²				
16259495	1181099	0.07264057	0.06888348		1.42161E-05				
36619377	2405361	0.06568547			1.01422E-05				
33715844	2192552	0.06503032			1.47443E-05				
24937795	1731530	0.06943397			3.17891E-07				
33556373	2195508	0.06542745			1.18521E-05				
25816636	1829507	0.07086543			3.98115E-06				
30285249	2006757	0.06626186			6.80315E-06				
25237322	1744784	0.06913507			7.01835E-08				
21534298	1516776	0.07043536			2.44989E-06				
22686536	1676973	0.07391931			2.5494E-05				

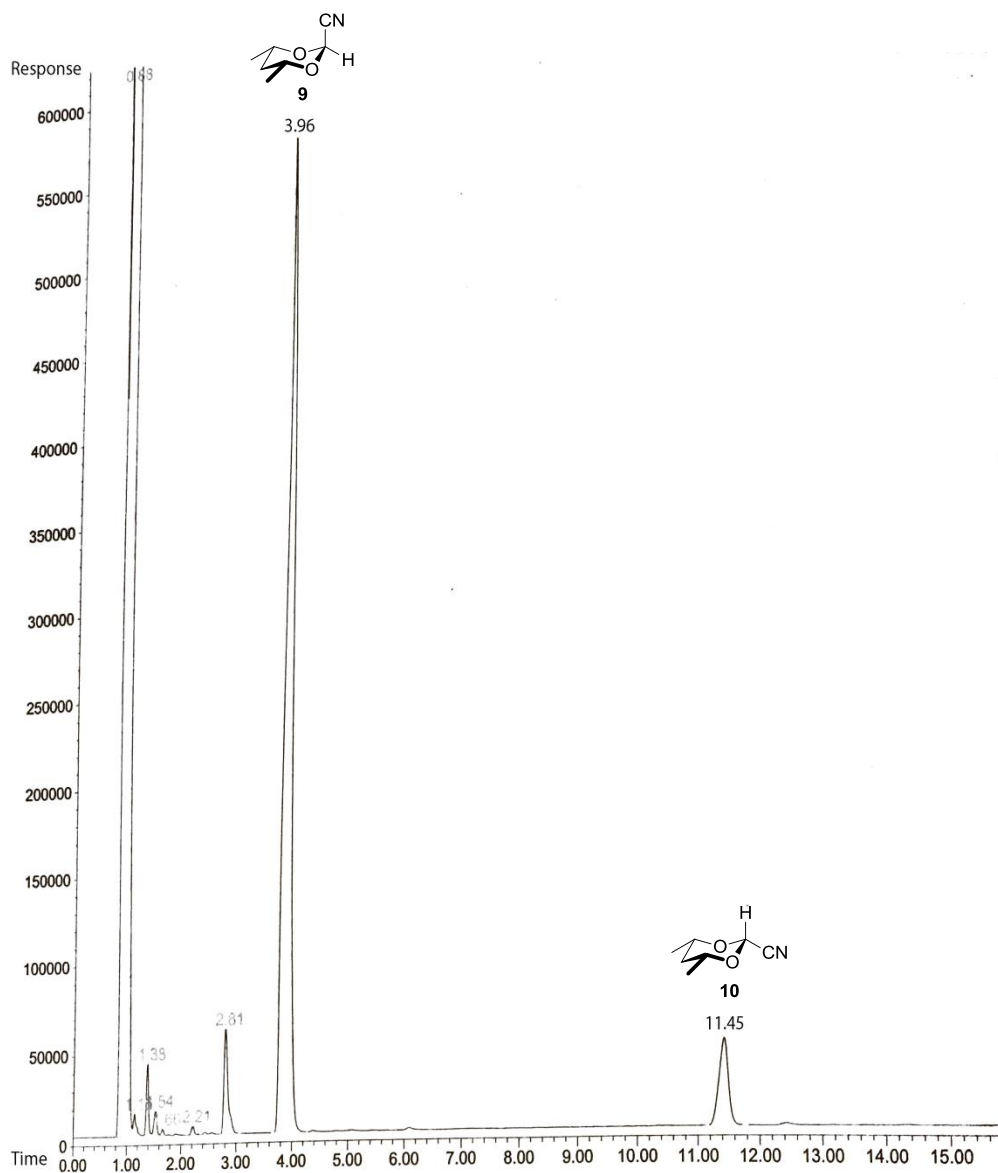



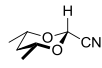
GC column: Optima[®] 225; 50% cyanopropyl, 50% phenylmethyl polysiloxane; 30 meters; id- 0.25 mm; film- 0.25 μm

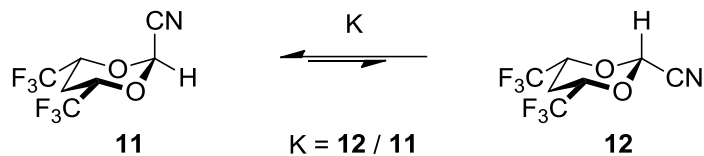
Program Description

The initial temperature was set at 100 °C for five minutes and increased at a rate of 2 °C/min and held at a final temperature of 170 °C for a period of 10 min.

Compound	Ret. Time
9	3.96 min
10	11.45 min



<div><div> 9</div><div>\xrightleftharpoons{K}</div><div> 10</div></div> <div>K = 10 / 9</div>									
Equilibrium study from <i>r</i> -2-Cyano- <i>trans</i> -4, <i>trans</i> -6-dimethyl-1,3-dioxane (10) in ether									
Area of axial cyano isomer (9)	Area of equatorial cyano isomer (10)	K	K _{Av}	Overall \bar{K}	(K - \bar{K}) ²	$\Sigma(K - \bar{K})^2$	S _m = 1/[n(n-1)] ^{1/2} $\Sigma[(K - \bar{K})^2]^{1/2}$	ΔG°=-RTlnK	ΔG° with error reported
23736356	4680179	0.19717344	0.20084545	0.20603	7.83746E-05	0.0012	0.001778299	0.92972954	0.930 +/- 0.005 kcal/mol
16565149	3358003	0.20271493			1.09657E-05			0.9246715	-0.005058041
21817345	4515603	0.20697308			8.96227E-07			0.93483143	-0.005101889
39351885	7528854	0.19132131			0.000216239				
43908362	8457997	0.19262839			0.000179506				
27777954	5647926	0.20332405			7.30262E-06				
40998431	8934377	0.21791997			0.000141457				
28643977	5733960	0.2001803			3.41766E-05				
48209034	9412187	0.195237			0.000116411				
43472348	8737163	0.20098208			2.5445E-05				
Equilibrium study from <i>r</i> -2-Cyano- <i>cis</i> -4, <i>cis</i> -6-dimethyl-1,3-dioxane (10) in ether									
Area of axial cyano isomer (9)	Area of equatorial cyano isomer (10)	K	K _{Av}		(K - \bar{K}) ²				
50538338	10604903	0.20983878	0.21120731		1.45343E-05				
50346136	10778253	0.21408302			6.49095E-05				
54033965	11273637	0.20863982			6.83008E-06				
51627944	10710936	0.20746393			2.06653E-06				
41126351	9012070	0.21913128			0.000171738				
71180646	14929970	0.2097476			1.38475E-05				
39819860	8425614	0.21159326			3.09901E-05				
72179144	15072239	0.20881709			7.78806E-06				
78116961	16259723	0.20814587			4.49224E-06				
91822937	19706346	0.21461246			7.37206E-05				
Equilibrium study from <i>r</i> -2-Cyano- <i>trans</i> -4, <i>trans</i> -6-dimethyl-1,3-dioxane (9) in cyclohexane									
Area of axial cyano isomer (9)	Area of equatorial cyano isomer (10)	K	K _{Av}	Overall \bar{K}	(K - \bar{K}) ²	$\Sigma(K - \bar{K})^2$	S _m = 1/[n(n-1)] ^{1/2} $\Sigma[(K - \bar{K})^2]^{1/2}$	ΔG°=-RTlnK	ΔG° with error reported
23869540	2434059	0.10197344	0.10167335	0.10194	1.13493E-09	5.4E-05	0.000375541	1.34383179	1.344 +/- 0.002 kcal/mol
22878240	2351051	0.10276363			6.78784E-07			1.34166766	-0.002164129
23203916	2375448	0.10237272			1.87466E-07			1.3460039	-0.002172117
23241074	2360198	0.10155288			1.49666E-07				
18547280	1897278	0.10229414			1.25592E-07				
39072721	3837263	0.09820824			1.39242E-05				
30797638	3045683	0.0988934			9.28026E-06				
18905743	1954063	0.10335817			2.01192E-06				
23263152	2387142	0.10261473			4.55599E-07				
23250785	2387907	0.10270221			5.8135E-07				
Equilibrium study from <i>r</i> -2-Cyano- <i>cis</i> -4, <i>cis</i> -6-dimethyl-1,3-dioxane (10) in cyclohexane									
Area of axial cyano isomer (9)	Area of equatorial cyano isomer (10)	K	K _{Av}		(K - \bar{K}) ²				
46609887	4871363	0.10451351	0.10220614		6.62427E-06				
65261616	6797101	0.10415159			4.89225E-06				
83126940	8379513	0.10080382			1.29033E-06				
58999109	6008463	0.10183989			9.97061E-09				
63196037	6346437	0.1004246			2.29566E-06				
84510625	8414448	0.09956675			5.63113E-06				
61456910	6216603	0.10115385			6.17635E-07				
48487516	5011819	0.10336308			2.02588E-06				
72537464	7485980	0.10320157			1.59219E-06				
49005193	5049629	0.10304273			1.21658E-06				

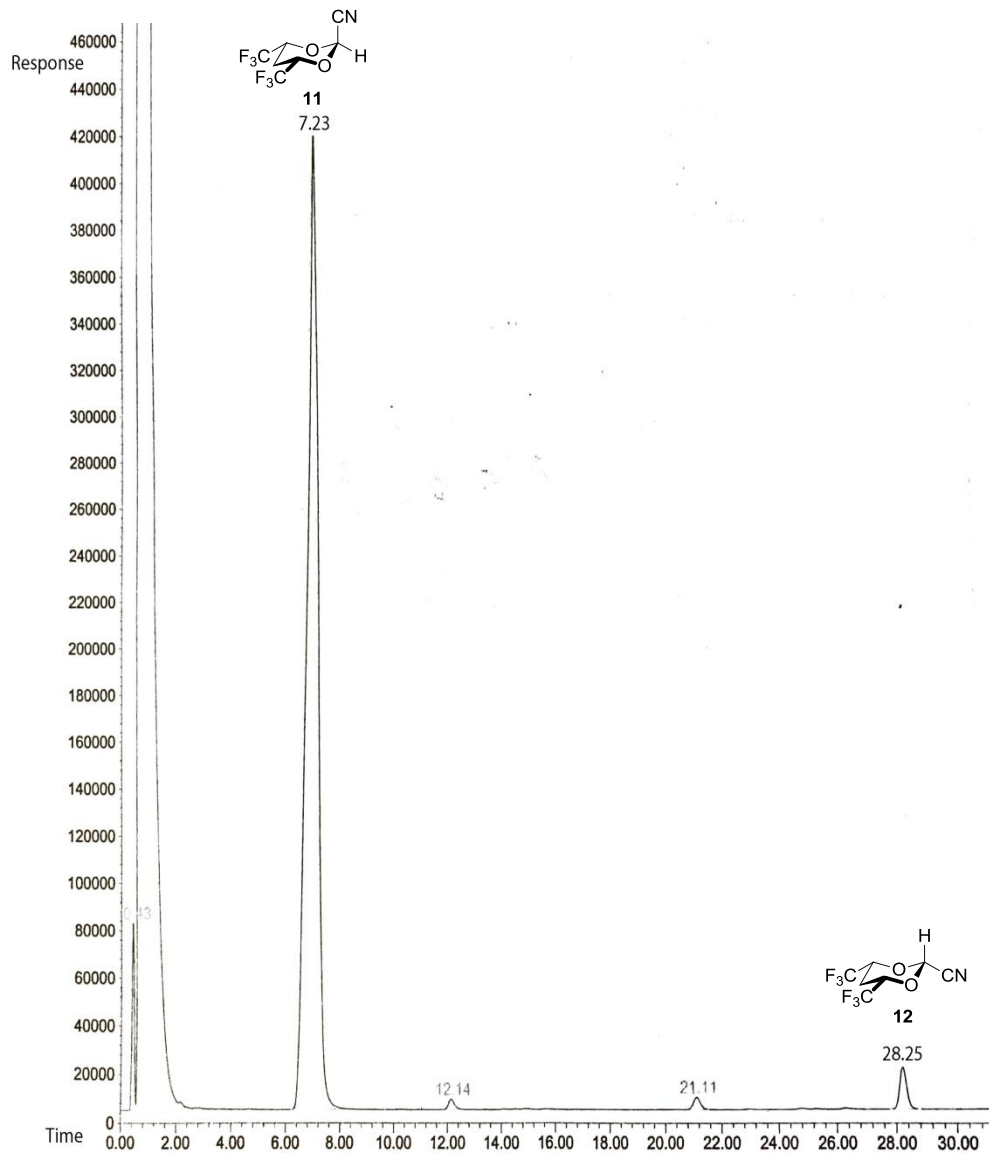


GC column: Optima[®] 225; 50% cyanopropyl, 50% phenylmethyl polysiloxane; 30 meters; id- 0.25 mm; film- 0.25 μm

Program Description

The initial temperature was set at 60 °C for five minutes and increased at a rate of 2 °C/min and held at a final temperature of 170 °C for a period of 10 min.

Compound	Ret. Time
11	7.23 min
12	28.25 min



<div style="text-align: center;"> <p>11 \xrightleftharpoons{K} 12</p> <p>$K = 12 / 11$</p> </div>									
Equilibrium study from <i>r</i> -2-Cyano- <i>trans</i> -4, <i>trans</i> -6-bistrifluoromethyl-1,3-dioxane (11) in ether									
Area of axial cyano isomer (11)	Area of equatorial cyano isomer (12)	K	K_{Av}	Overall \bar{K}	$(K - \bar{K})^2$	$\Sigma(K - \bar{K})^2$	$S_m = 1/[n(n-1)]^{1/2} \Sigma[(K - \bar{K})^2]^{1/2}$	$\Delta G^\circ = -RT \ln K$	ΔG° with error reported
128135507	3797044	0.02963304	0.03046834	0.02821	2.03236E-06	0.0002	0.000721746	2.09997205	2.10 +/- 0.01 kcal/mol
228381394	6731491	0.02947478			1.60618E-06			2.08510274	-0.014869313
163764742	4963505	0.03030875			4.41557E-06			2.1152268	-0.015254748
181742476	5369613	0.02954517			1.78957E-06				
232679310	6324963	0.02718318			1.04909E-06				
182853859	4864768	0.02660468			2.5688E-06				
184721631	6144782	0.03326509			2.558E-05				
212323158	6766914	0.03187082			1.34205E-05				
166615481	5150888	0.03091482			7.32999E-06				
138741066	4978454	0.03588306			5.89153E-05				
Equilibrium study from <i>r</i> -2-cyano- <i>cis</i> -4, <i>cis</i> -6-bistrifluoromethyl-1,3-dioxane (12) in ether									
Area of axial cyano isomer (11)	Area of equatorial cyano isomer (12)	K	K_{Av}		$(K - \bar{K})^2$				
116382652	3098356	0.02662215	0.02594651		2.51311E-06				
161968989	3881908	0.02396698			1.79814E-05				
160606250	3604821	0.02244509			3.32046E-05				
109025216	2753159	0.0252525			8.73161E-06				
138457830	3530546	0.02549907			7.33519E-06				
109672643	3053553	0.02784243			1.33222E-07				
129531997	3464687	0.02674773			2.13071E-06				
109132144	3094064	0.02835154			2.07678E-08				
129899585	3365096	0.02590536			5.29949E-06				
244859834	6570151	0.02683229			1.89099E-06				

References Chapter II Section 2.4

- ¹ The standard deviation from the mean (root mean square deviation) was determined for each series of measurements and this value was propagated to give the errors reported in Table 1. See, H. Margenau, H.; Murphy, G. M. *The Mathematics of Chemistry and Physics*; Van Nostrand: Princeton, N.J., 1968, pp. 504-515.
- ² Bekkum, H. V.; Verkade, P. E.; Wepster, B. M. *Proc. Kon. Ned. Akad. Wetensch., B*. **1961**, *64*, 161–164.
- ³ Kelly, C. B.; Lambert, K. M.; Mercadante, M. A.; Ovian, J. M.; Bailey, W. F.; Leadbeater, N. E. *Angew. Chem. Int. Ed.* **2015**, *54*, 4241–4245.
- ⁴ Eliel, E. L.; Nader, F. W. *J. Am. Chem. Soc.* **1970**, *92*, 584–590.
- ⁵ Pure *meso*-2,4-pentanediol was obtained in two steps. A 70:30 mixture of *meso* and *d,l*-2,4-pentanediol was obtained from the sodium borohydride reduction of 2,4-pentanedione as described by Pritchard and Vollmer: Pritchard, J. G.; Vollmer, R. L. *J. Org. Chem.* **1963**, *28*, 1545–1549. This *meso* enriched mixture was then subjected to the efficient separation process described by Zhang and coworkers: Pan, H.; Tu, S.; Zhang, C.; Young, A.; Fontaine, P. P. *Org. Process. Res. Dev.* **2015**, *19*, 463–469, to afford pure *meso*-2,4-pentanediol.
- ⁶ These compounds were reported in the following thesis: Murphy, K. D. Syntheses towards 5-Methylcytosine Analogs & Synthesis and Reactivity of Novel SHEA Acids Utilizing Hydrogen Bonding Networks. Ph.D. Dissertation, University of Minnesota, Minneapolis, MN, January 2011. Also see a) Shokri, A.; Kass, S. R. *Chem. Commun.* **2013**, *49*, 11674–11676. b) Shokri, A.; Wang, X. B.; Kass, S. R. *J. Am. Chem. Soc.* **2013**, *135*, 9525–9530. c) Jeulin, S.; Paule, S. D. D.; Ratovelomanana-Vidal, V.; Genet, J. P.; Champion, N.; Dellis, P. *Angew. Chem. Int. Ed.* **2004**, *43*, 320–325.
- ⁷ A complex solvent/diol azeotrope of unknown composition sometimes arises leading to removal of the diol from the reaction mixture. This can be detected by the appearance of a milky, turbid lower layer in the Dean-Stark trap within 1 h of the reaction mixture refluxing. The azeotrope can be easily dealt with by cooling the reaction mixture to room temperature, emptying the contents of the Dean-Stark trap back into the reaction flask and adding 2–3 mL of deionized water to the reaction mixture before continuing to reflux.
- ⁸ The filtrate contained the excess racemic 1,1,1,5,5,5-hexafluoro-2,4-pentanediol.
- ⁹ These aqueous layers were extracted with two 100 mL portions of Et₂O, dried over Na₂SO₄, and solvent removed to afford the racemic 1,1,1,5,5,5-hexafluoro-2,4-pentanediol as a white crystalline solid. This diol was not of interest in this present study, however, it had the following properties: mp 75.1–76.0 °C (Et₂O); ¹H NMR (400 MHz, CDCl₃) δ 1.99 (dd, *J* = 7.5, Hz, *J* = 5.7, 2H), 2.69 (d, *J* = 5.8 Hz, 2H), 4.30–4.40 (m, 2H); ¹³C NMR (100 MHz, CD₂Cl₂) δ 29.3, 66.6 (quartet, *J*_{C-F} = 32.1 Hz), 125.1 (quartet, *J*_{C-F} = 281.3 Hz); ¹⁹F NMR (376 MHz, CD₂Cl₂) δ –79.7; HRMS (DART-TOF) *m/z* calcd for C₅H₆F₆O₂ [M + H]⁺ 213.0350, found 213.0366.
- ¹⁰ The hexane extraction facilitates the removal of benzaldehyde; the *meso* diol is not significantly soluble in hexanes and remains in the aqueous layer.
- ¹¹ It is essential to ensure no excess diol remains as its separation from the title compounds is unsuccessful through column chromatography. If excess diol remained, additional aqueous K₂CO₃ washings were necessary.
- ¹² The vapor-pressure of the title compounds appears to be extremely low and care has to be taken during solvent removal to prevent evaporation and loss of the product.
- ¹³ GC-MS analysis was conducted using a 25 m × 0.20 mm × 0.33 μm DB-5 5% Phenyl / 95% Dimethyl polysiloxane column and the following temperature program: 5 min. at an initial temperature = 40 °C then a gradual increase in temperature at a rate of 15 °C/min. to a final temperature = 240 °C which is held constant for 20 min. A solvent delay of 2 min. was used and compounds of interest eluted in the following order at the given retention times: trimethyl orthoformate, 2.60 min.; the *trans*-isomer (**7**), 5.95 min.; the *cis*-isomer (**8**), 6.20 min.; *meso*-1,1,1,5,5,5-hexafluoro-2,4-pentanediol, 7.30 min.
- ¹⁴ Anderson, M. A.; Shim, H.; Raushel, F. M.; Cleland, W. W. *J. Am. Chem. Soc.* **2001**, *123*, 9246–9253.
- ¹⁵ Bhatta, C. S.; Susanta, D.; Utpal, S. *J. Indian Chem. Soc.* **1998**, *78*, 46–38.
- ¹⁶ Banala, A. K.; Zhang, P.; Plenge, P.; Cyriac, G.; Kopajtic, T.; Katz, J. L.; Loland, C. L. Newman, A. M. *J. Med. Chem.* **2013**, *56*, 9709–9724.
- ¹⁷ Alvarez, M.; Fernandez, D.; Joule, J. A.; *Tetrahedron Lett.* **2001**, *42*, 315–317.
- ¹⁸ Balenovic, K.; Bregnant, N.; Galijan, T. *Arhiv. Za Kemiju.* **1954**, *26*, 233–234.
- ¹⁹ Lambert, K. M.; Bobbitt, J. M.; Eldirany, S. A.; Kissane, L. E.; Sheridan, R. K.; Stempel, Z. D.; Sternberg, F. H.; Bailey, W. F. *Chem. Eur. J.* **2016**, *22*, 5156–5159.

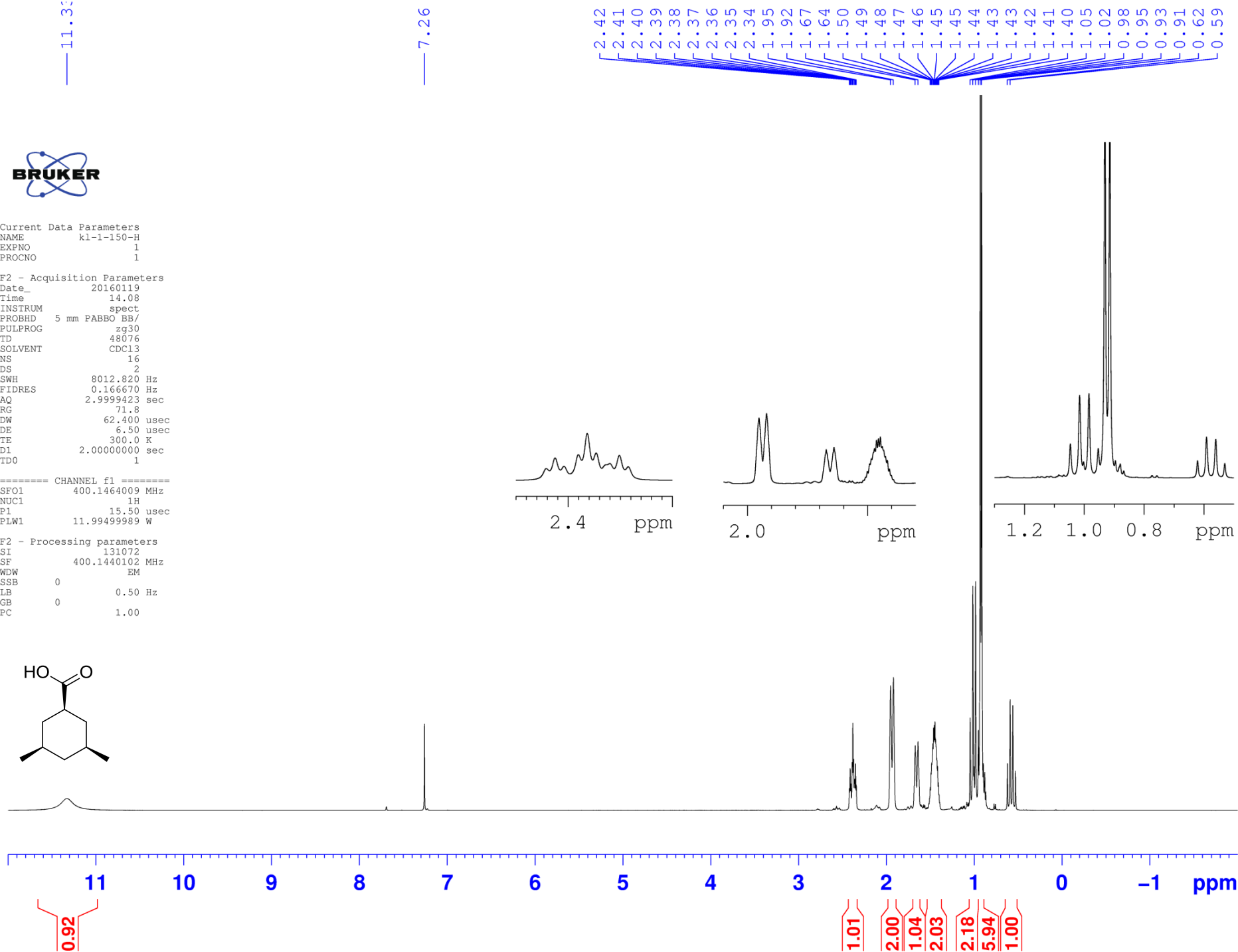
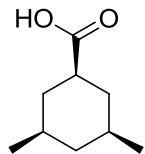


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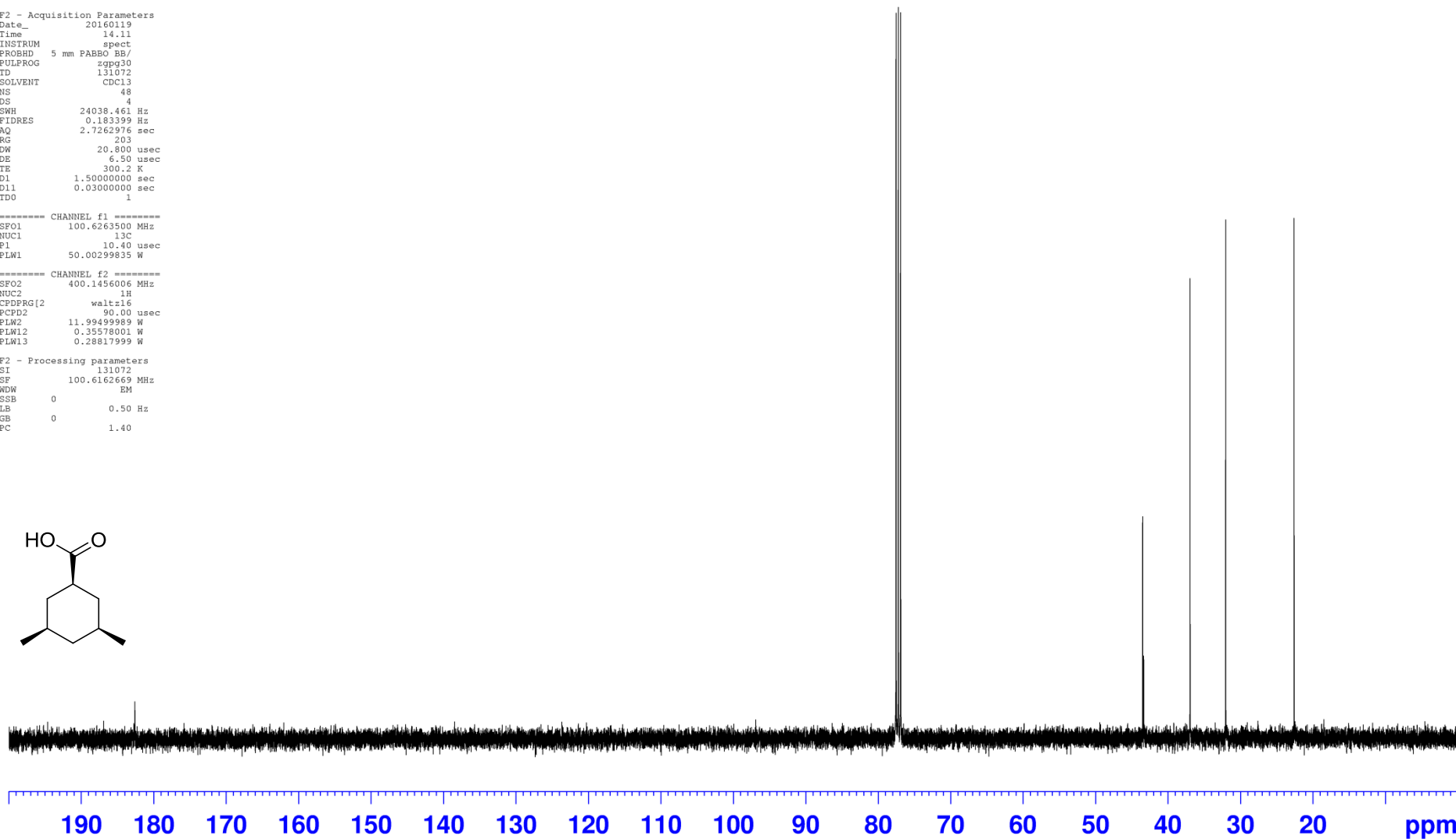
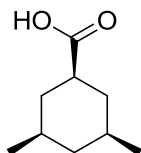
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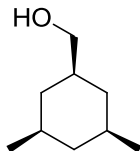


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1.42
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1.40
1.39
1.38
1.38
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1.08
1.08
0.56
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677

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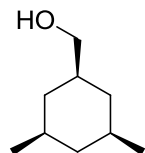
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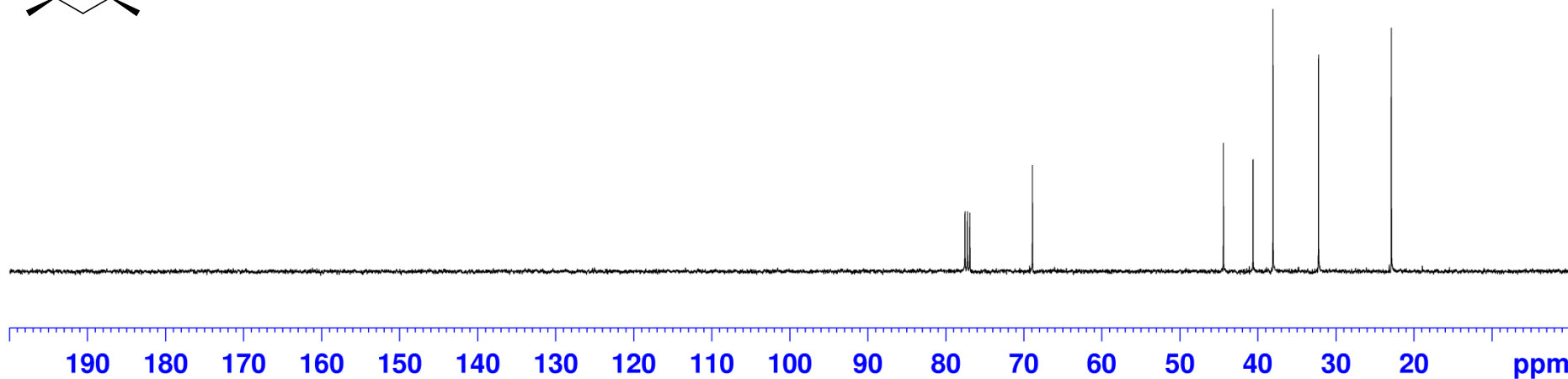
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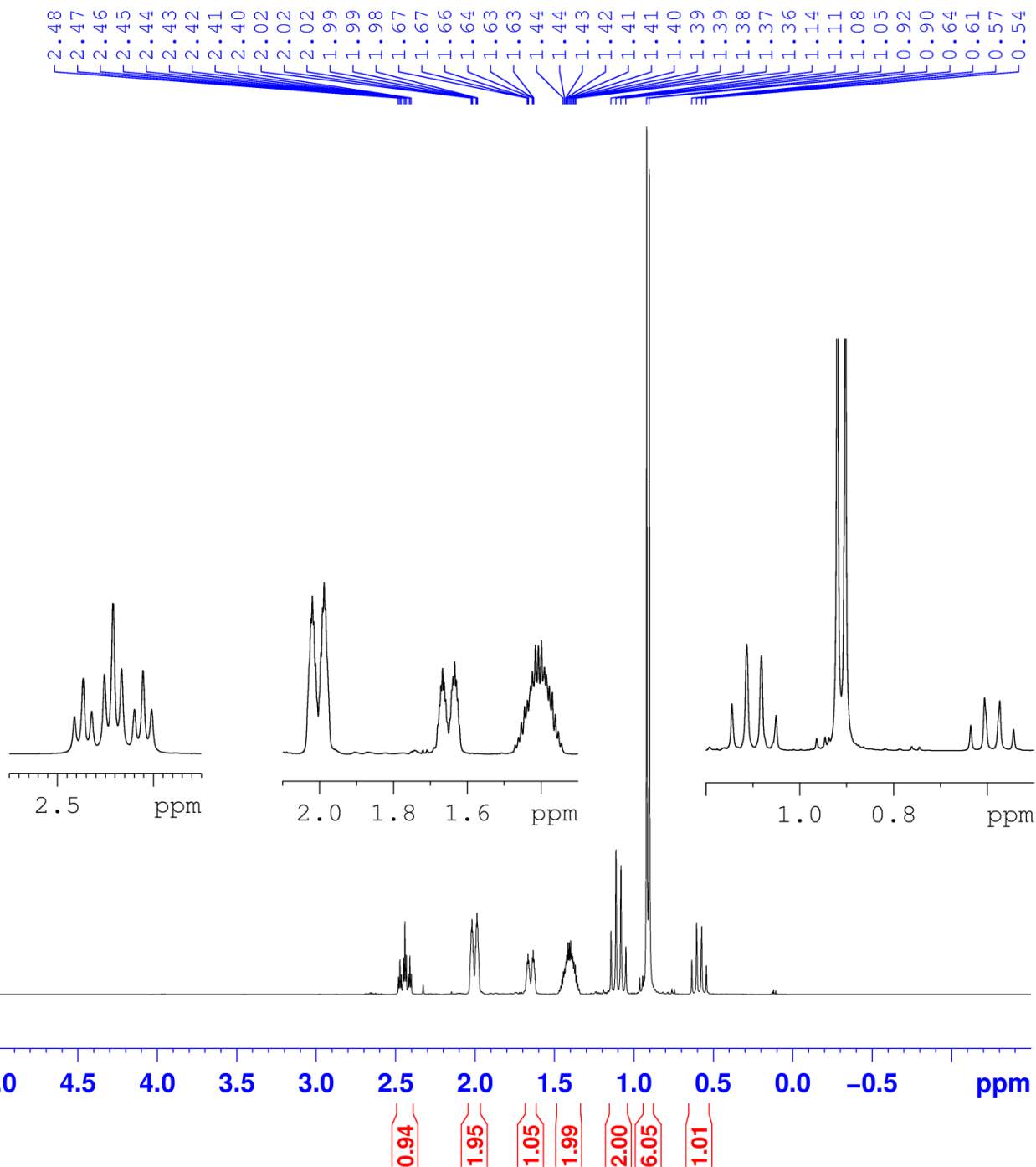
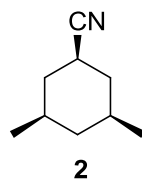


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RG 32
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TE 300.0 K
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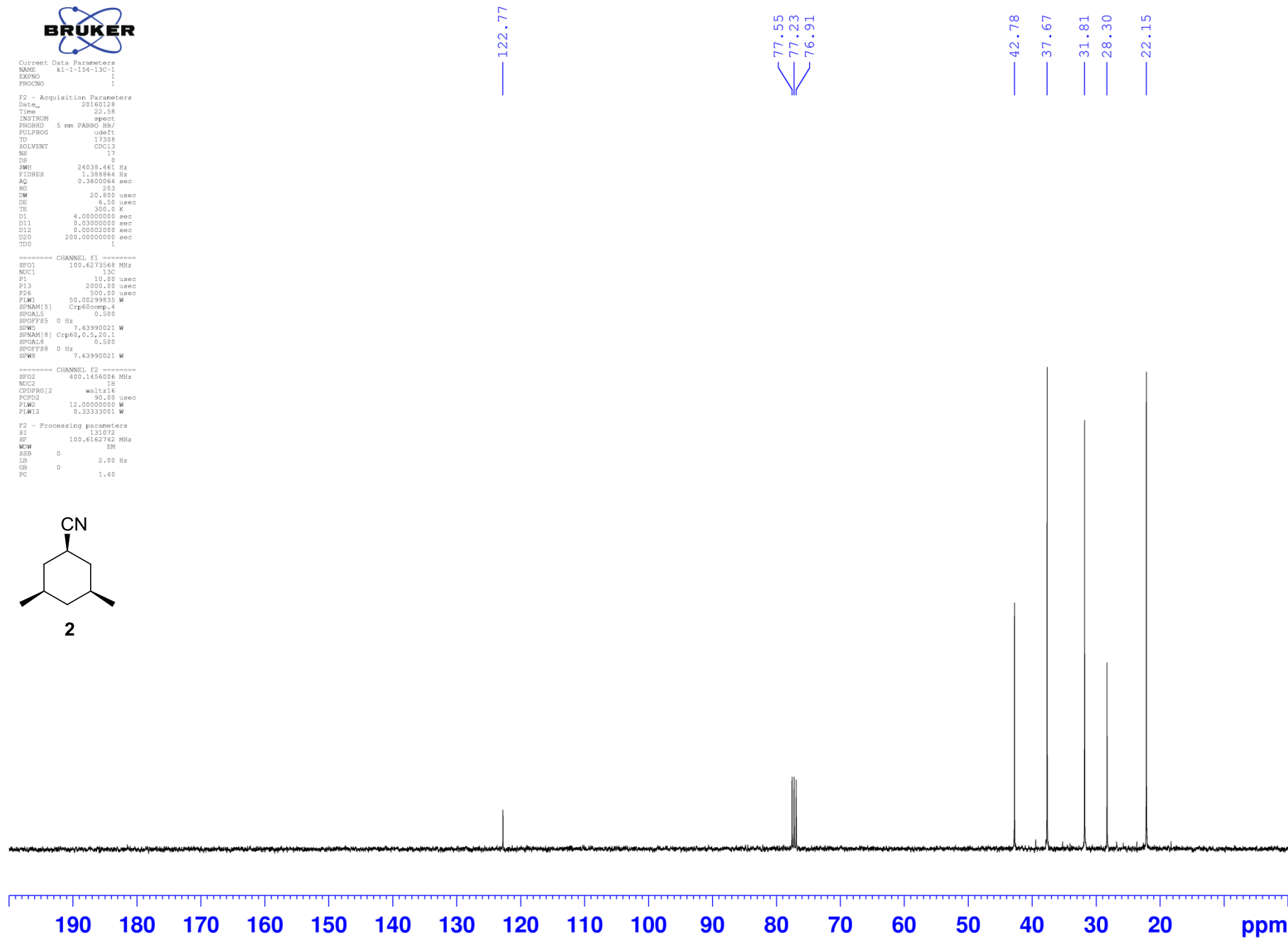
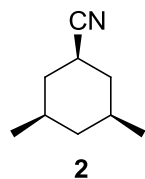
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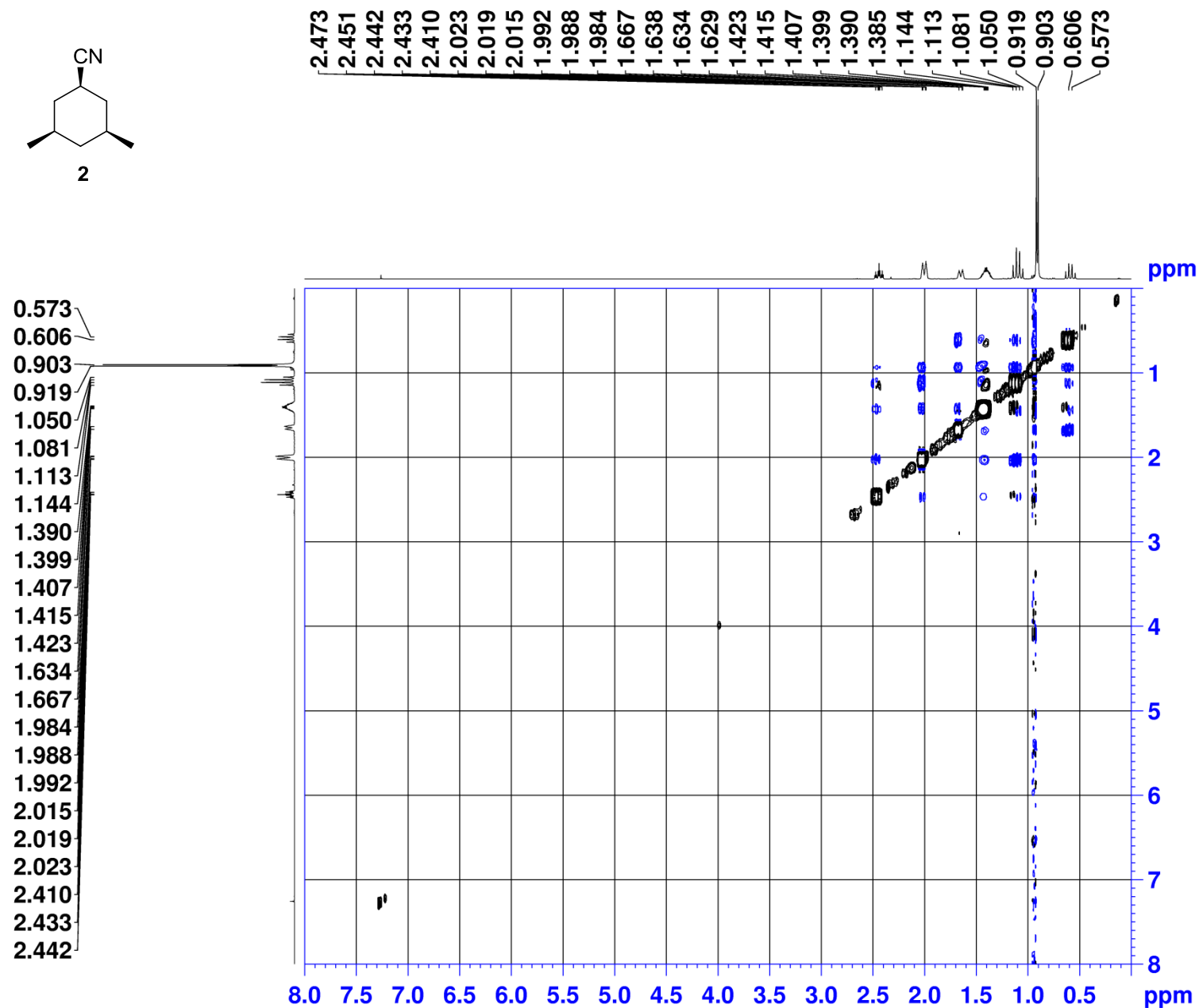
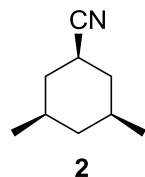
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WDW EM
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 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 D0 0.00010330 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec

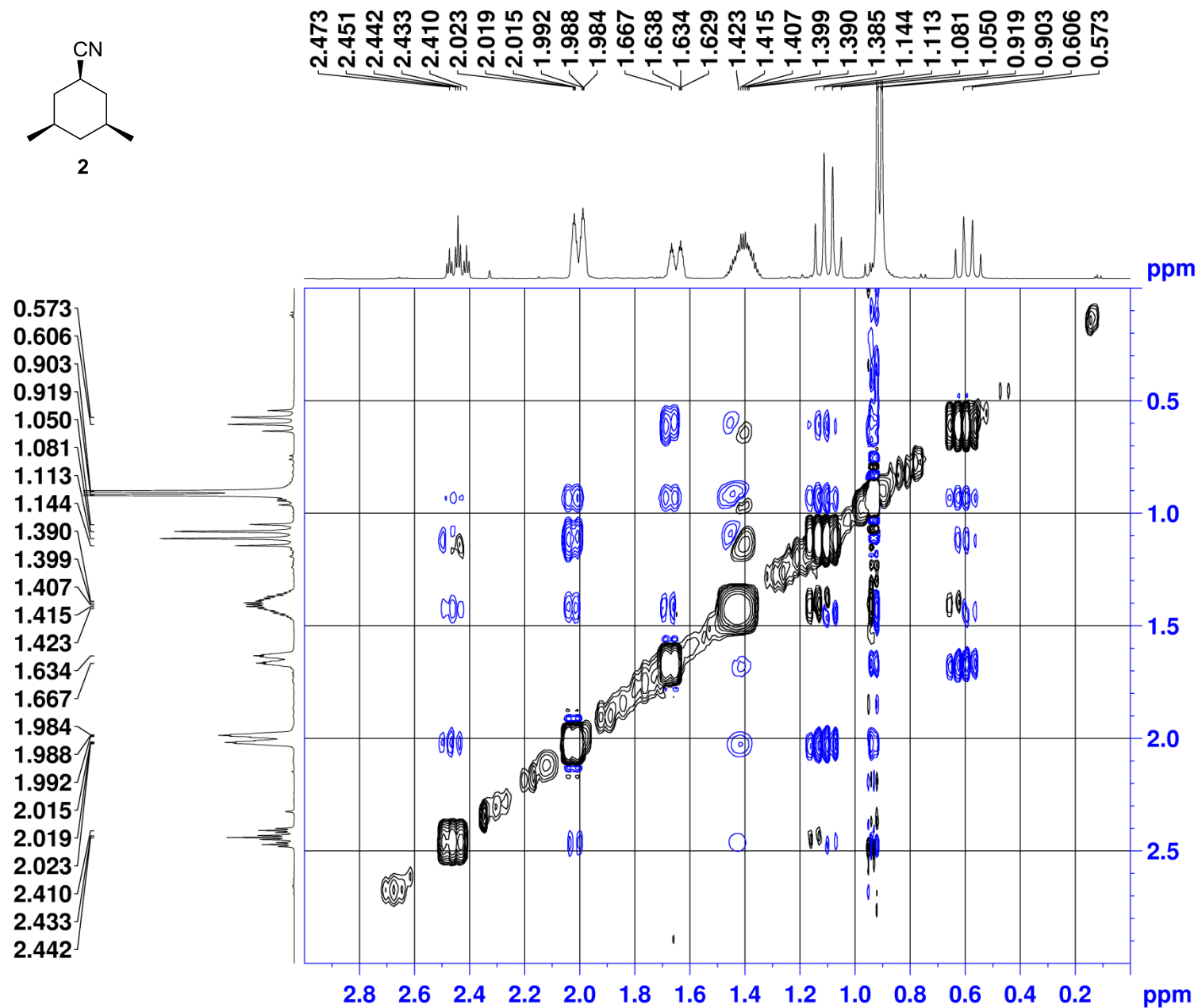
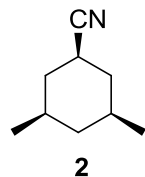
===== CHANNEL f1 =====
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.00 usec
 P2 30.00 usec
 P17 2500.00 usec
 PLW1 12.00000000 W
 PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FMODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0



Current Data Parameters
 NAME kl-1-154-HNOCESY-1
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20160128
 Time 23.53
 INSTRUM spect
 PROBHD 5 mm FABBO BB/
 PULPROG noesygpphpg
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 32
 SWH 4084.967 Hz
 FIDRES 1.994613 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 DO 0.00010330 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec

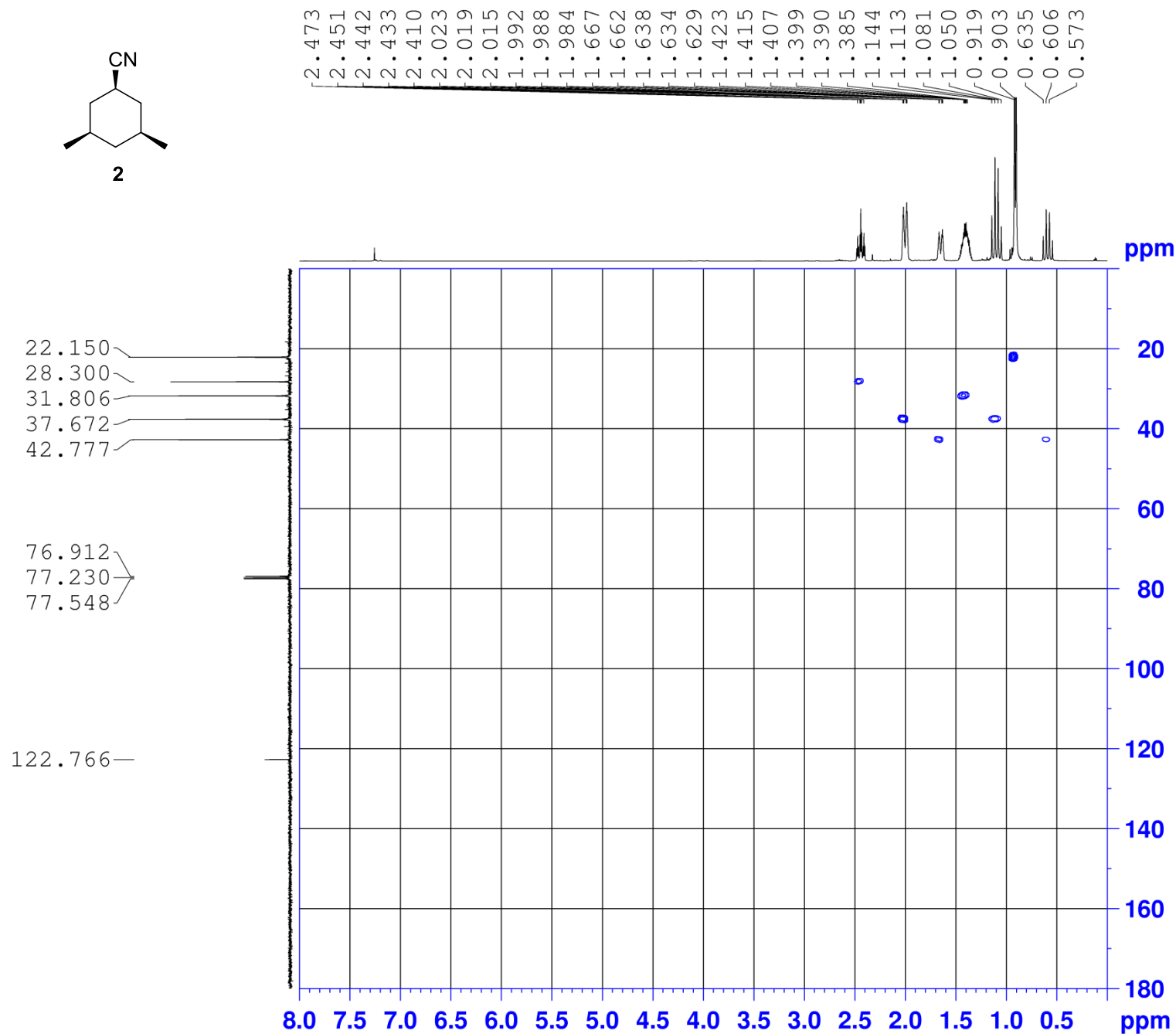
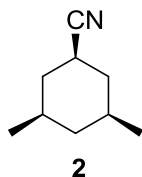
===== CHANNEL f1 =====
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.00 usec
 P2 30.00 usec
 P17 2500.00 usec
 PLW1 12.00000000 W
 PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FMODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0



Current Data Parameters
NAME kl-1-154-HSQC-1
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160128
Time 23.00
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG hsqcetdcp1sp2.3
TD 1024
SOLVENT CDCl3
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNS12 145.000000
CNS117 -0.500000
D0 0.00000300 sec
D1 1.50000000 sec
D4 0.0012414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.00360000 sec
D24 0.00089000 sec
INO 0.00003010 sec

===== CHANNEL f1 =====
SFO1 400.1458807 MHz
NUC1 1H
P1 15.25 usec
P2 30.50 usec
P28 1000.00 usec
PLW1 12.00000000 W

===== CHANNEL f2 =====
SFO2 100.623320 MHz
NUC2 13C
CPOPRG[2] bi_p5m4sp4cp-2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1800.00 usec
P63 1500.00 usec
PLW2 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SPOAL3 0.500
SPOFS3 0 Hz
SPW3 7.63940001 W
SPW7 7.63940001 W
SPW14 3.25950003 W
SPW18 1.83050001 W
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPNAM[3] SMSQ10.100
GPNAM[4] SMSQ10.100
GP21 80.00 %
GP22 20.10 %
GP23 11.00 %
GP24 -5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 128
SFO1 100.6233 MHz
FIDRES 129.775742 Hz
SW 165.084 ppm
FMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.612890 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0

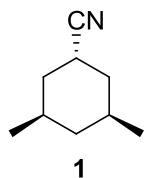


Current Data Parameters
NAME kl-1-164-axial-H1
EXPNO 1
PROCNO 1

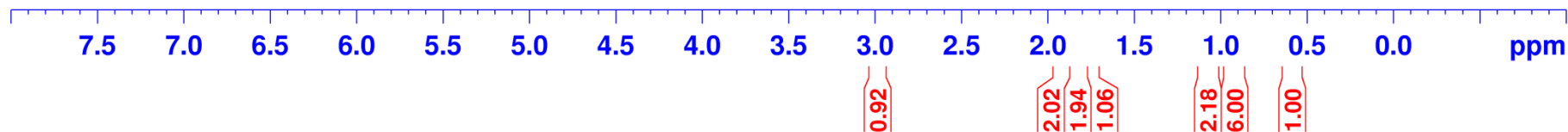
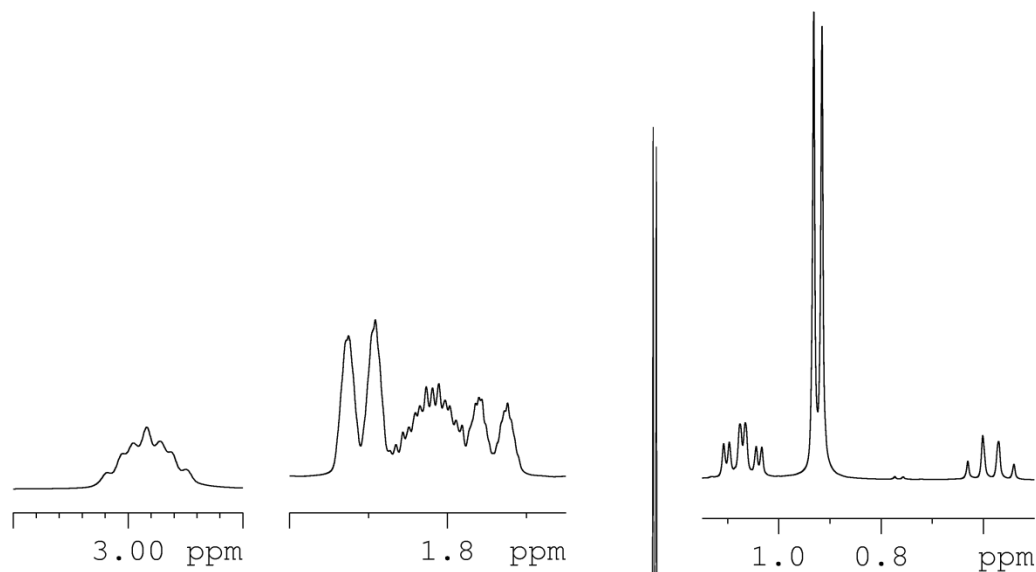
F2 - Acquisition Parameters
Date_ 20160205
Time 17.52
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDC13
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 80.6
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440096 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00



3.01
3.00
2.99
2.99
2.97
1.93
1.89
1.87
1.86
1.85
1.84
1.84
1.83
1.82
1.81
1.80
1.80
1.79
1.78
1.76
1.76
1.72
1.11
1.10
1.08
1.06
1.04
1.03
0.93
0.91
0.63
0.60
0.57
0.54





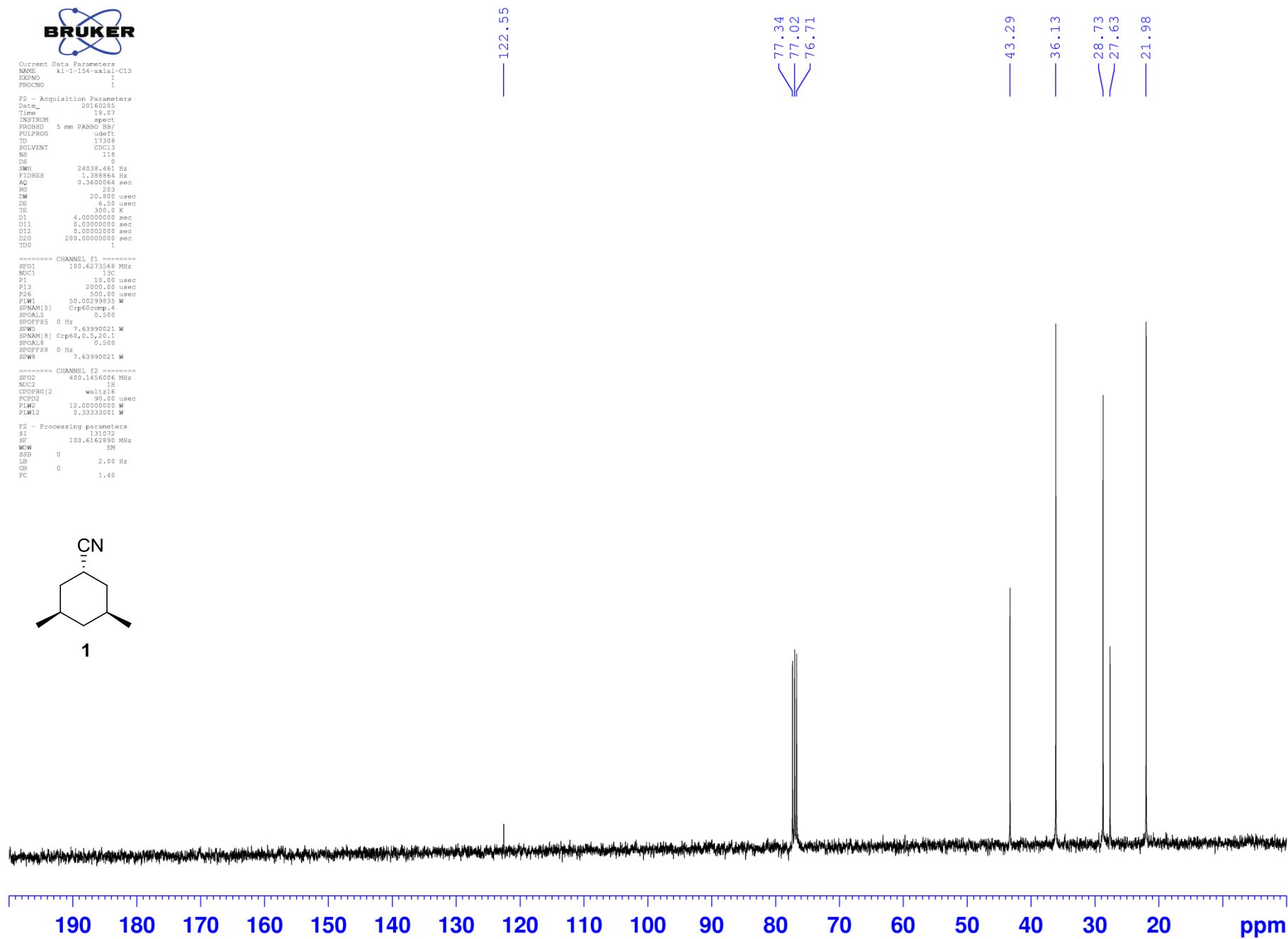
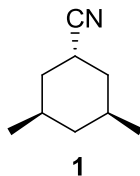
Current Data Parameters
NAME k1-2-156-axial-C13
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160205
Time 19.07
INSTRUM spect
PROBHD 5 mm PARBO BB/
PULPROG udefc
TD 17398
SOLVENT CDCl3
NS 119
DS 0
SWH 24038.461 Hz
FIDRES 1.388864 Hz
AQ 0.3600064 sec
RG 203
RW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 4.00000000 sec
D11 0.03000000 sec
D12 0.00000000 sec
D20 200.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6273568 MHz
NUC1 13C
P1 10.00 usec
P13 2000.00 usec
P26 500.00 usec
PLW1 50.00299835 W
SPNAM[5] Crp60comp.4
SFOAL5 0 Hz 0.500
SFOFF5 0 Hz
SPW5 7.63990021 W
SPNAM[8] Crp60,0.5,20.1
SFOAL8 0 Hz 0.500
SFOFF8 0 Hz
SPW8 7.63990021 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG[2] waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W

F2 - Processing parameters
SI 131072
SF 100.6162890 MHz
WDW EM
SSB 0
LB 2.00 Hz
GB 0
PC 1.40





Current Data Parameters
 NAME kl-1-154-axial-HNOESY
 EXPNO 1
 PROCNO 1

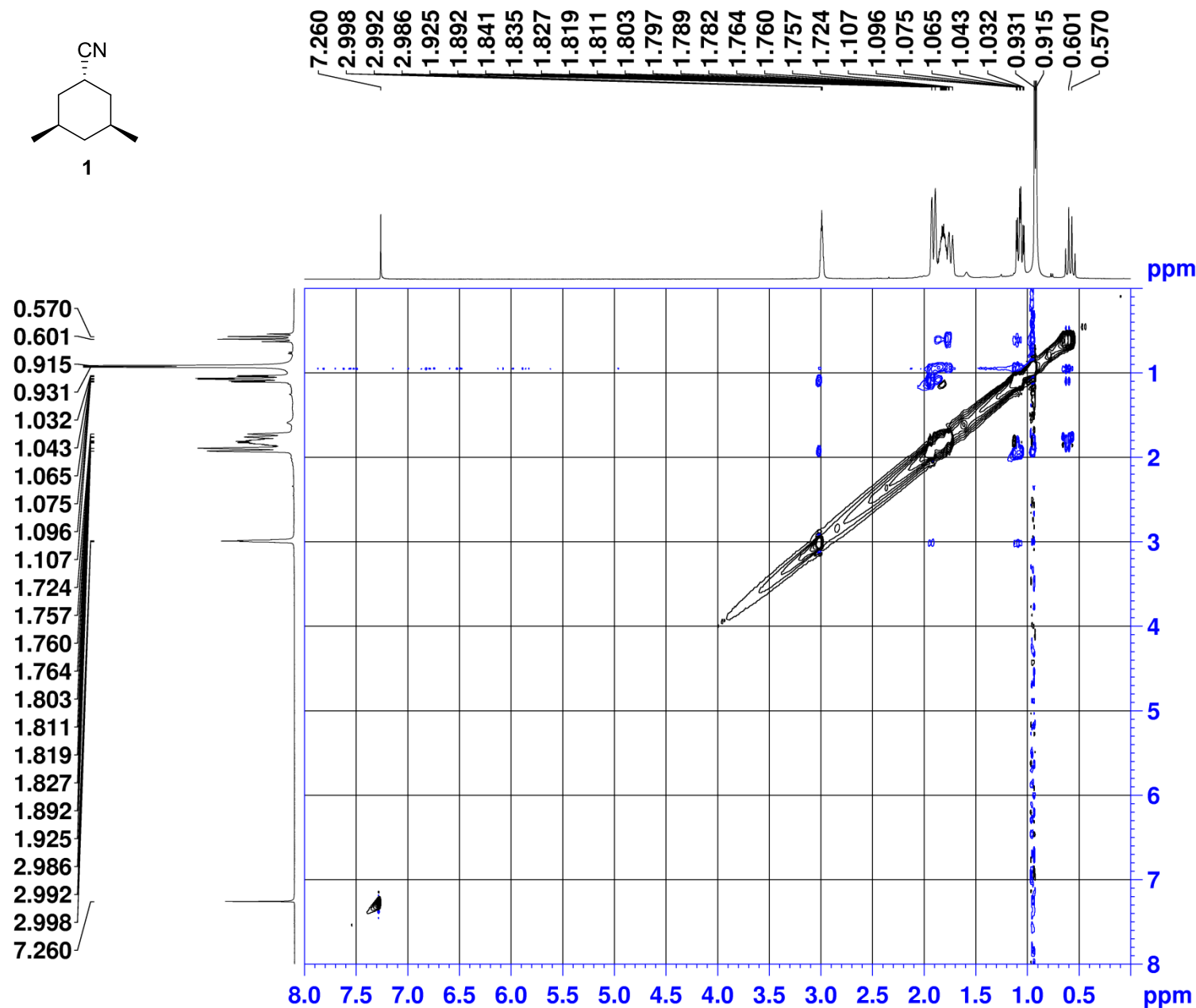
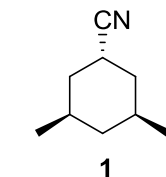
F2 - Acquisition Parameters
 Date_ 20160208
 Time 23.02
 INSTRUM spect
 PROBHD 5 mm FABBO BB/
 PULPROG noesygpgppp
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 32
 SWH 4084.967 Hz
 FIDRES 1.994613 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 D0 0.00010330 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec

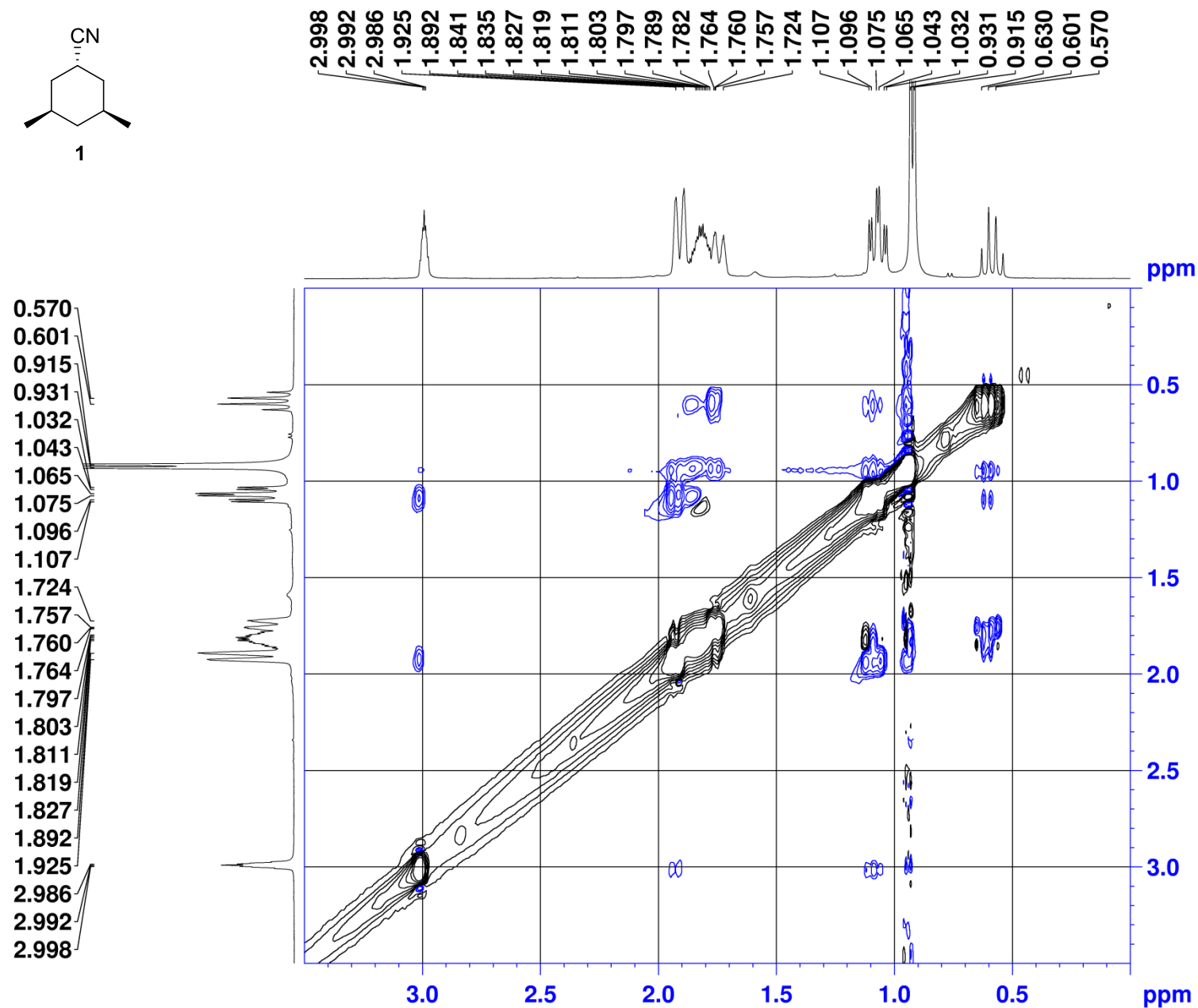
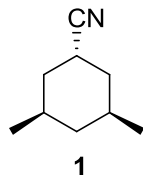
===== CHANNEL f1 =====
 SF01 400.1458419 MHz
 NUC1 1H
 P1 15.00 usec
 P2 30.00 usec
 P17 2500.00 usec
 PLW1 12.00000000 W
 PLW10 3.99410009 W
 ===== GRADIENT CHANNEL =====
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SF01 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FnmODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0





Current Data Parameters
 NAME kl-1-154-axial-HNOESY
 EXPNO 1
 PROCNO 1

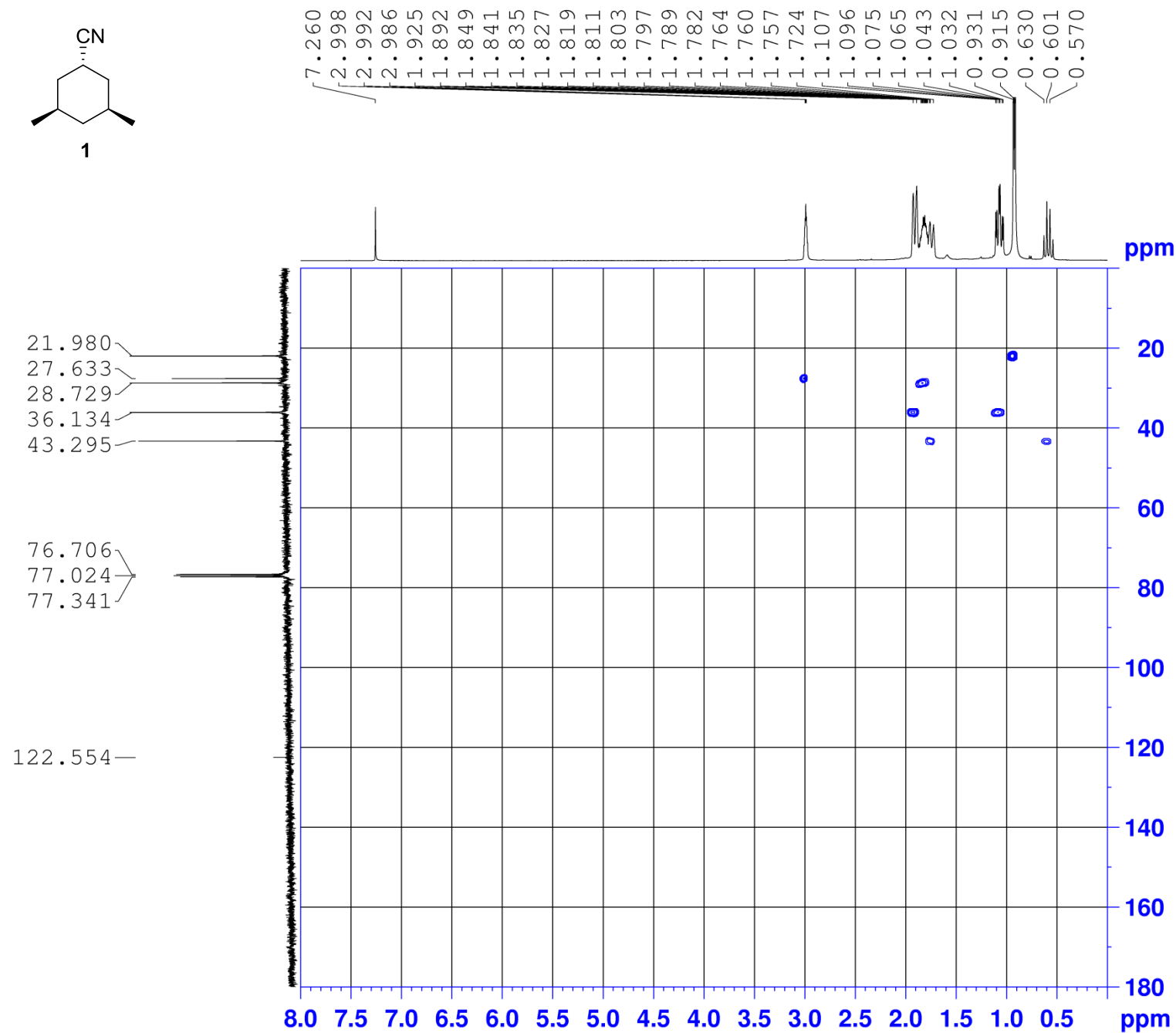
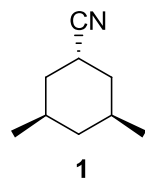
F2 - Acquisition Parameters
 Date_ 20160208
 Time 23.02
 INSTRUM spect
 PROBHD 5 mm FABBO BB/
 PULPROG noesygpphpg
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 32
 SWH 4084.967 Hz
 FIDRES 1.994613 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 DO 0.00010330 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 INO 0.00024480 sec

===== CHANNEL f1 =====
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.00 usec
 P2 30.00 usec
 P17 2500.00 usec
 PLW1 12.00000000 W
 PLW10 3.99410009 W
 ===== GRADIENT CHANNEL =====
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FnmODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0



Current Data Parameters
NAME kl-1-154-axial-HSQC
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160205
Time 18.12
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG haqcudetgsp1sp2.3
TD 1024
SOLVENT CDCl3
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNS12 145.000000
CNS117 -0.500000
D0 0.00000300 sec
D1 1.50000000 sec
D4 0.0012414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.00360000 sec
D24 0.00089000 sec
INO 0.00003010 sec

===== CHANNEL f1 =====
SFO1 400.1458807 MHz
NUC1 1H
P1 15.25 usec
P2 30.50 usec
P28 1000.00 usec
PLW1 12.00000000 W

===== CHANNEL f2 =====
SFO2 100.623320 MHz
NUC2 13C
CPDPRG2 bi_p5m4sp4sp2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1800.00 usec
P63 1500.00 usec
PLW0 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SPOAL3 0.500
SPOFS3 0 Hz
SPW3 7.63940001 W
SPW7 7.63940001 W
SPNAM[14] Crp32,1.5,20.2
SPOAL14 0.500
SPOFS14 0 Hz
SPW14 3.25950003 W
SPNAM[18] Crp60_xf11c,2
SPOAL18 0.500
SPOFS18 0 Hz
SPW18 1.83050001 W
SPNAM[31] Crp32,1.5,20.2
SPOAL31 0.500
SPOFS31 0 Hz
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPNAM[3] SMSQ10.100
GPNAM[4] SMSQ10.100
GP21 80.00 %
GP22 20.10 %
GP23 11.00 %
GP24 -5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 128
SFO1 100.6233 MHz
FIDRES 129.775742 Hz
SW 165.084 ppm
FMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WFW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.612890 MHz
WFW QSINE
SSB 2
LB 0 Hz
GB 0

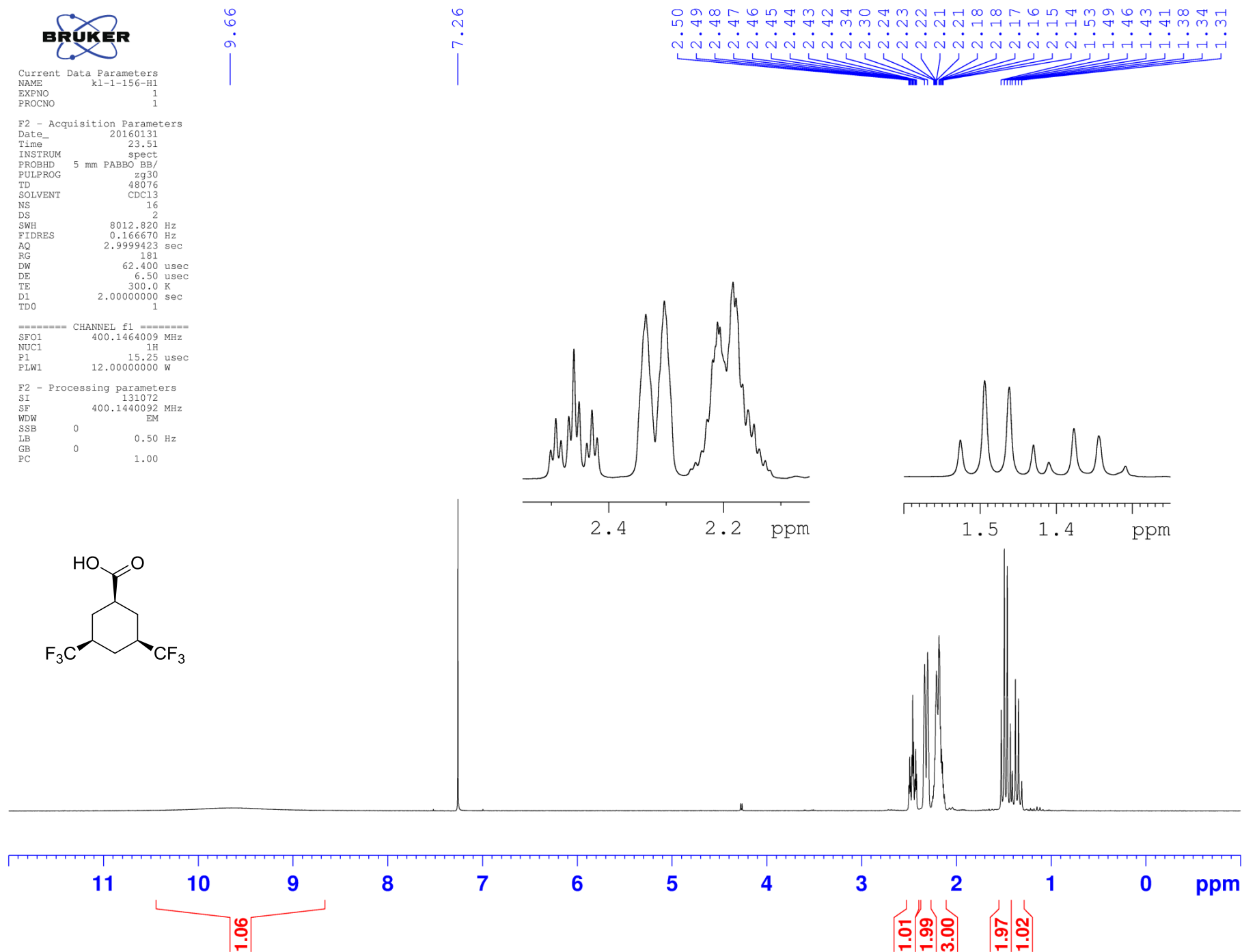
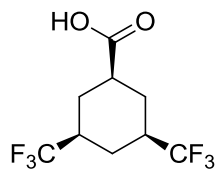


Current Data Parameters
NAME kl-1-156-H1
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160131
Time 23.51
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 181
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440092 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00





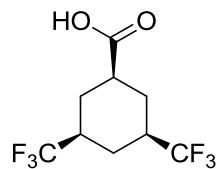
Current Data Parameters
NAME kl-1-156-C13
EXNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160201
Time 0.04
INSTRUM spect
PROBHD 5 mm PARBO BB/
PULPROG udef1
TD 17308
SOLVENT CDCl3
NS 154
DS 0
SWH 24038.461 Hz
FIDRES 1.388864 Hz
AQ 0.3600064 sec
RG 203
DW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 4.00000000 sec
D11 0.03000000 sec
D12 0.00002000 sec
D20 200.00000000 sec
TDO 1

***** CHANNEL f1 *****
SFO1 100.6273568 MHz
NUC1 13C
P1 10.00 usec
P13 2000.00 usec
P26 500.00 usec
PLW1 50.00299835 W
SPNAM[5] Crp60comp.4
SFOAL5 0 Hz
SPOPF55 0 Hz
SPW5 7.639900021 W
SPNAM[8] Crp60,0.5,20.1
SFOAL8 0 Hz
SPOPF58 0 Hz
SPW8 7.639900021 W

***** CHANNEL f2 *****
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG[2] waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W

F2 - Processing parameters
S1 131072
SF 100.6160662 MHz
WDW EM
SSB 0
LB 2.00 Hz
GB 0
PC 1.40



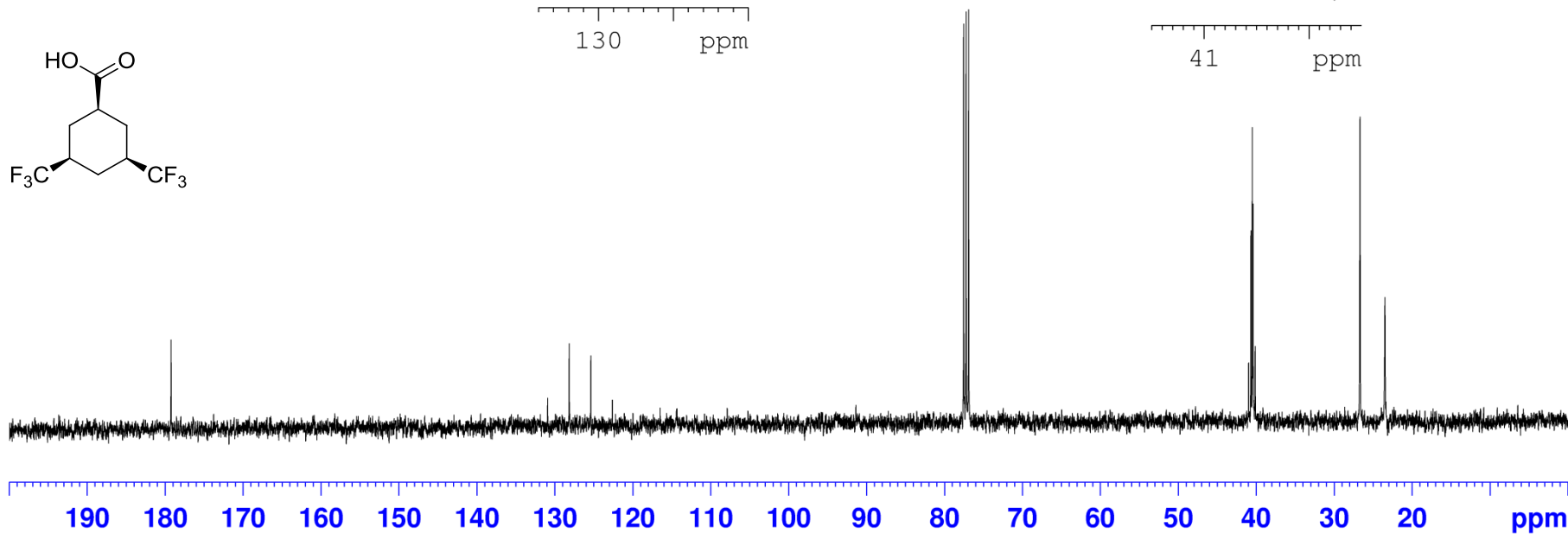
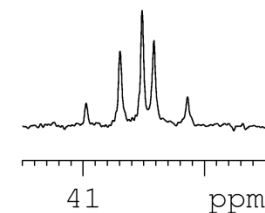
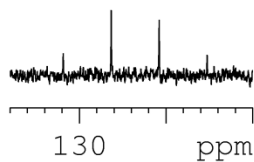
179.24

130.93
128.16
125.39
122.62

77.55
77.23
76.91

40.97
40.70
40.51
40.42
40.14

26.73
26.71
26.68
26.66
23.49





Current Data Parameters
NAME kl-1-156-F19
EXPNO 1
PROCNO 1

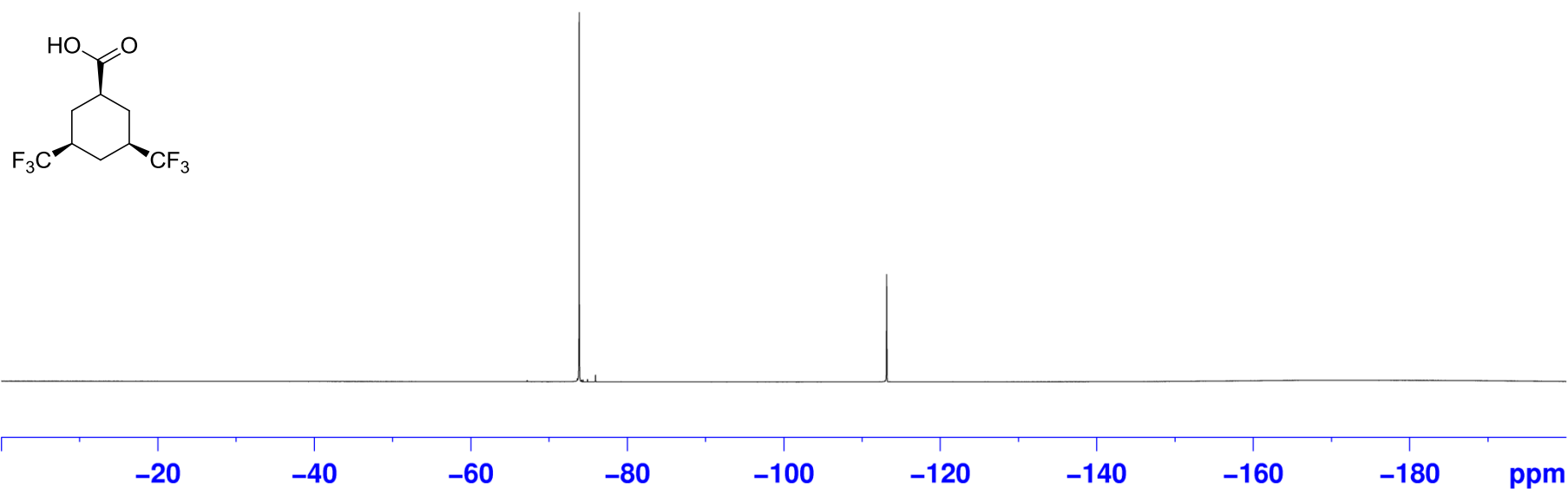
F2 - Acquisition Parameters
Date_ 20160201
Time 0.15
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg
TD 131072
SOLVENT CDCl3
NS 5
DS 0
SWH 89285.711 Hz
FIDRES 0.681196 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 3.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 376.4738882 MHz
NUC1 19F
P1 11.05 usec
PLW1 17.98900032 W

F2 - Processing parameters
SI 131072
SF 376.5115509 MHz
WDW EM
SSB 0
LB 5.00 Hz
GB 0
PC 1.00

— -73.83

— -113.15



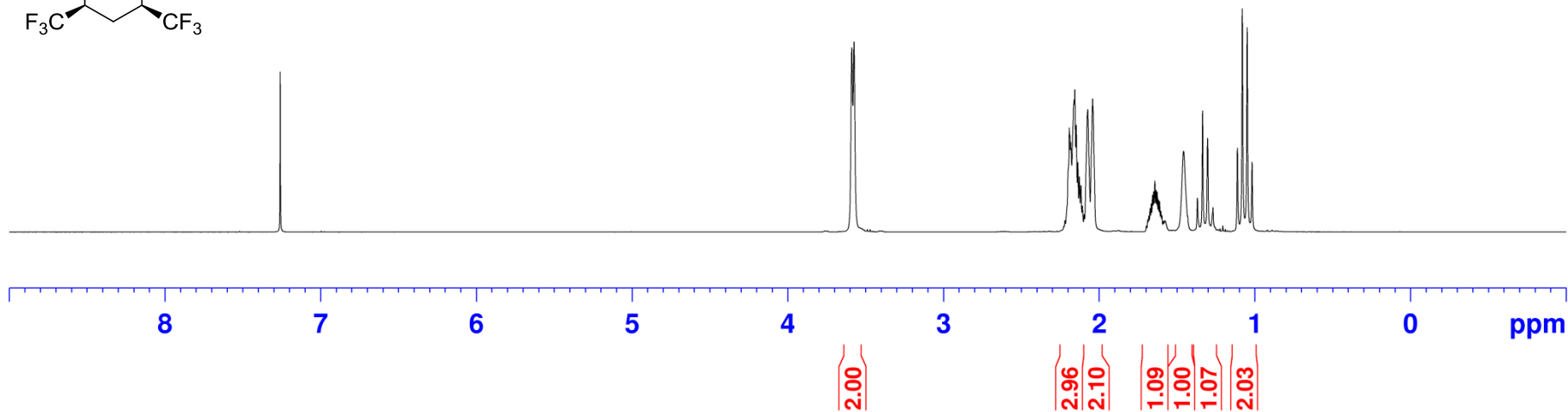
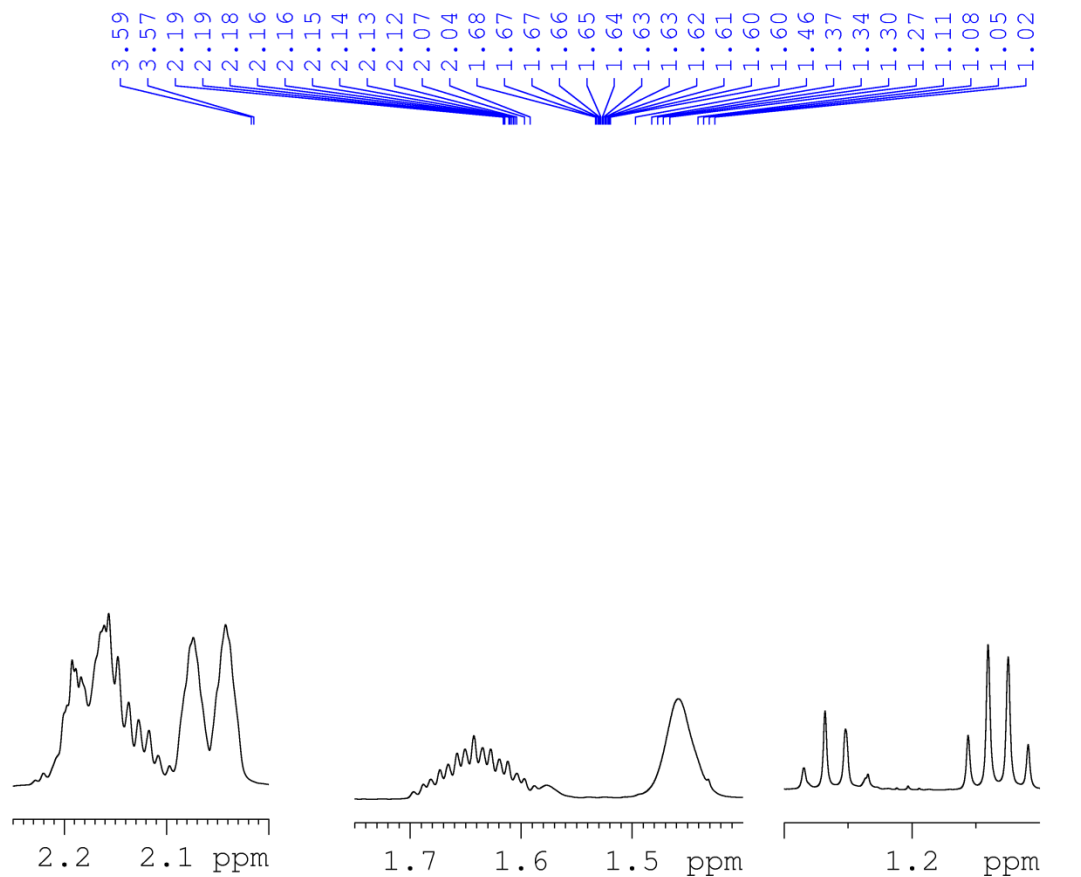
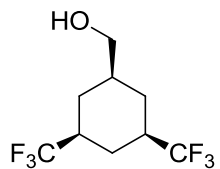


Current Data Parameters
NAME kl-1-158-H-1
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160204
Time 19.40
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 144
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440098 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00





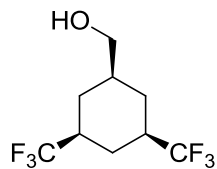
Current Data Parameters
NAME k1-2-158-C13-1
EXPNO 2
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160205
Time 14.17
INSTRUM spect
PROBHD 5 mm PARBO BB/
PULPROG udefc
TD 17398
SOLVENT CDCl3
NS 203
DS 0
SWH 24038.461 Hz
FIDRES 1.388864 Hz
AQ 0.3600064 sec
RG 203
RW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 4.00000000 sec
D11 0.03000000 sec
D12 0.00000000 sec
D20 200.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6273568 MHz
NUC1 13C
P1 10.00 usec
P13 2000.00 usec
P26 500.00 usec
PLW1 50.0029935 W
SPNAM[5] Crp60comp.4
SFOAL5 0 Hz
SFOFF5 0 Hz
SPW5 7.63990021 W
SPNAM[8] Crp60,0.5,20.1
SFOAL8 0.500
SFOFF8 0 Hz
SPW8 7.63990021 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPOPRG[2] waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W

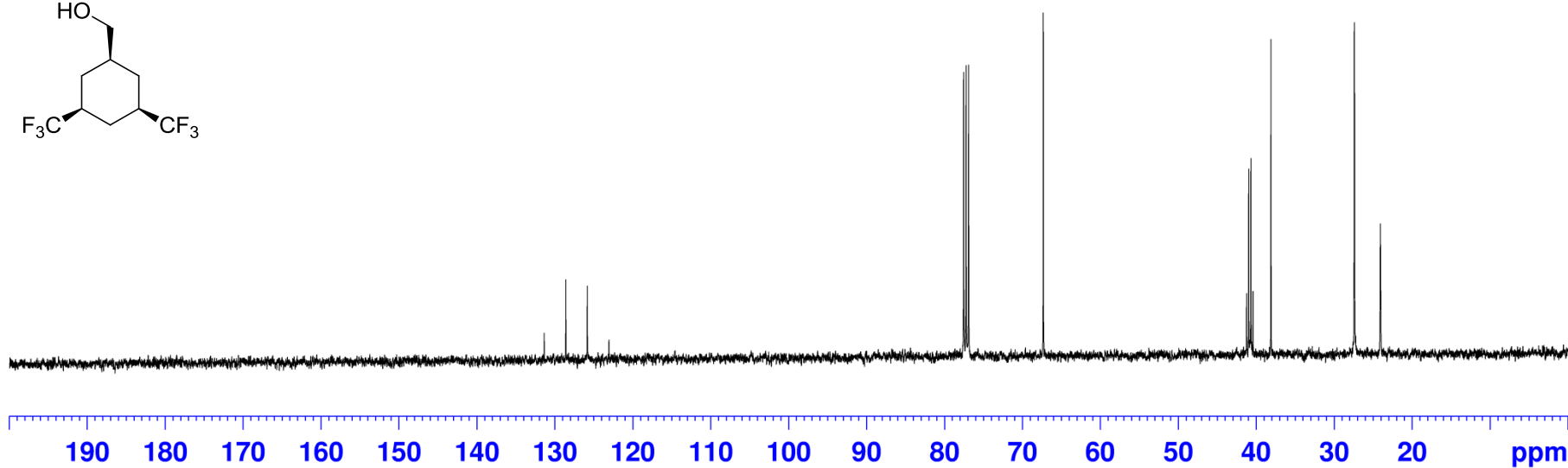
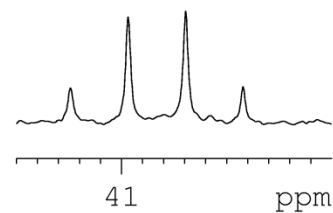
F2 - Processing parameters
SI 131072
SF 100.6162664 MHz
WDW EM
SSB 0
LB 2.00 Hz
GB 0
PC 1.40



131.37
128.60
125.83
123.06

77.55
77.23
76.91
67.33

41.24
40.97
40.69
40.42
38.12
27.44
27.42
27.40
27.37
24.14
24.12
24.09
24.07
24.04
24.02
24.01





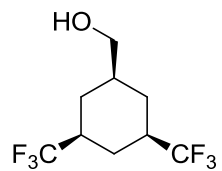
Current Data Parameters
NAME kl-1-158-F1
EXPHO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160204
Time 19.56
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgfhqgn.2
TD 131072
SOLVENT CDCl3
NS 12
DS 4
SWH 89285.711 Hz
FIDRES 0.681196 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 3.00000000 sec
D11 0.03000000 sec
D12 0.00002000 sec
TDO 1

===== CHANNEL f1 =====
SFO1 376.4738882 MHz
NUC1 19F
P1 14.00 usec
PLW1 17.98900032 W

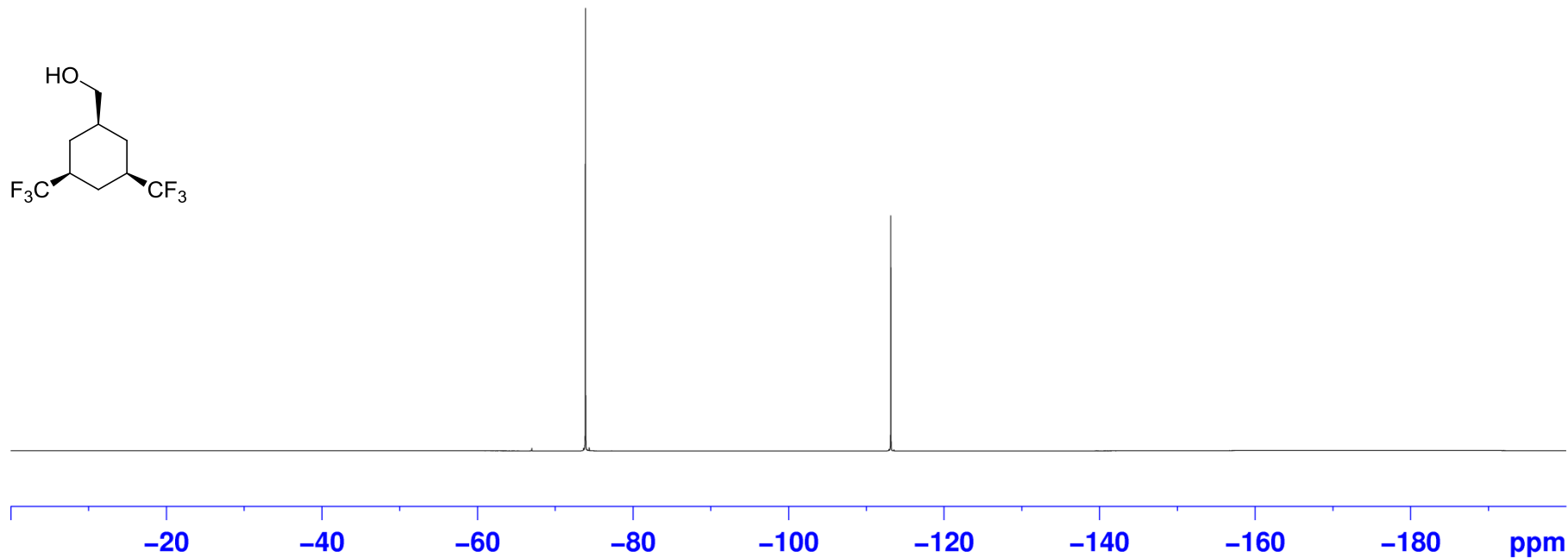
===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG[2] waltz16
PCPD2 90.00 usec
PLW2 11.99499989 W
PLW12 0.34439000 W

F2 - Processing parameters
SI 131072
SF 376.5115565 MHz
WDW EM
SSB 0
LB 5.00 Hz
GB 0
PC 1.00



— -73.89

— -113.15



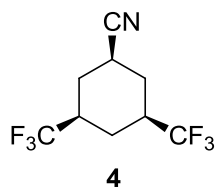


Current Data Parameters
NAME k1-l-161-H1
EXPNO 1
PROCNO 1

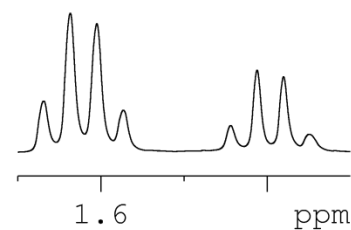
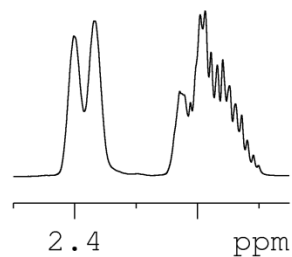
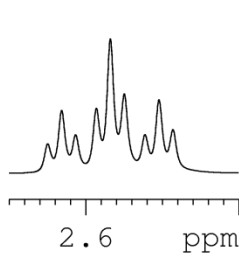
F2 - Acquisition Parameters
Date_ 20160212
Time 18.44
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDC13
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 80.6
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440098 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00



2.62
2.62
2.61
2.59
2.58
2.57
2.56
2.55
2.54
2.40
2.37
2.23
2.21
2.19
2.19
2.18
2.17
2.16
2.15
2.14
2.13
2.12
1.67
1.64
1.60
1.57
1.44
1.41
1.38
1.35



0.97
2.00
3.01
1.99
1.05



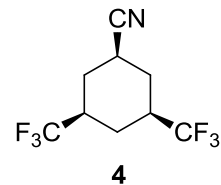
Current Data Parameters
NAME kl-1-161-C13
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160212
Time 19.07
INSTRUM spect
PROBHD 5 mm PARBO BB/
PULPROG udefc
TD 17398
SOLVENT CDCl3
NS 214
DS 0
SWH 24038.461 Hz
FIDRES 1.388864 Hz
AQ 0.3600064 sec
RG 203
RW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 4.00000000 sec
D11 0.03000000 sec
D12 0.00000000 sec
D20 200.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6273568 MHz
NUC1 13C
P1 10.00 usec
P13 2000.00 usec
P26 500.00 usec
PLW1 50.00299835 W
SPNAM[5] Crp60comp.4
SFOAL5 0 Hz
SFOFFS5 0 Hz
SPW5 7.63990021 W
SPNAM[8] Crp60,0.5,20.1
SFOAL8 0.500
SFOFFS8 0 Hz
SPW8 7.63990021 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPOPRG[2] waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W

F2 - Processing parameters
SI 131072
SF 100.6162673 MHz
WDW EM
SSB 0
LB 2.00 Hz
GB 0
PC 1.40

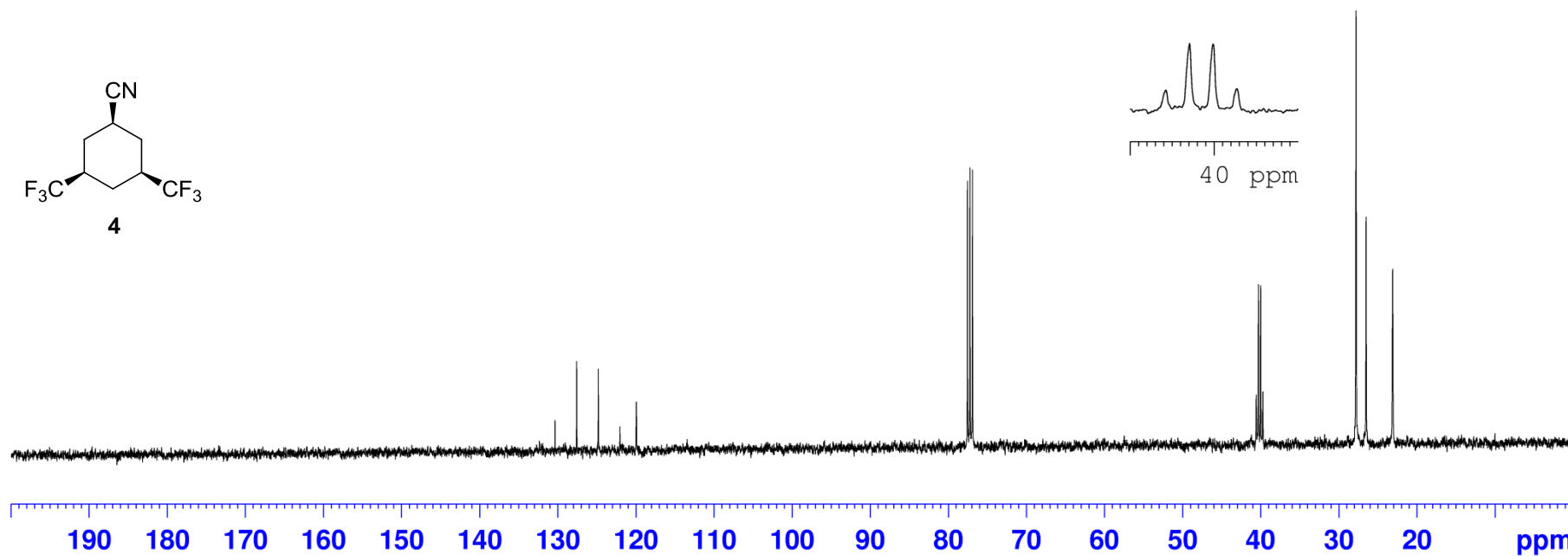


130.36
127.59
124.82
122.05
119.95

77.55
77.23
76.91

40.57
40.29
40.01
39.73

27.81
26.51
23.12





Current Data Parameters
NAME kl-1-161-F19
EXPHO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160212
Time 19.57
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgfhqgn.2
TD 131072
SOLVENT CDCl3
NS 8
DS 4
SWH 89285.711 Hz
FIDRES 0.681196 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 3.00000000 sec
D11 0.03000000 sec
D12 0.00002000 sec
TDO 1

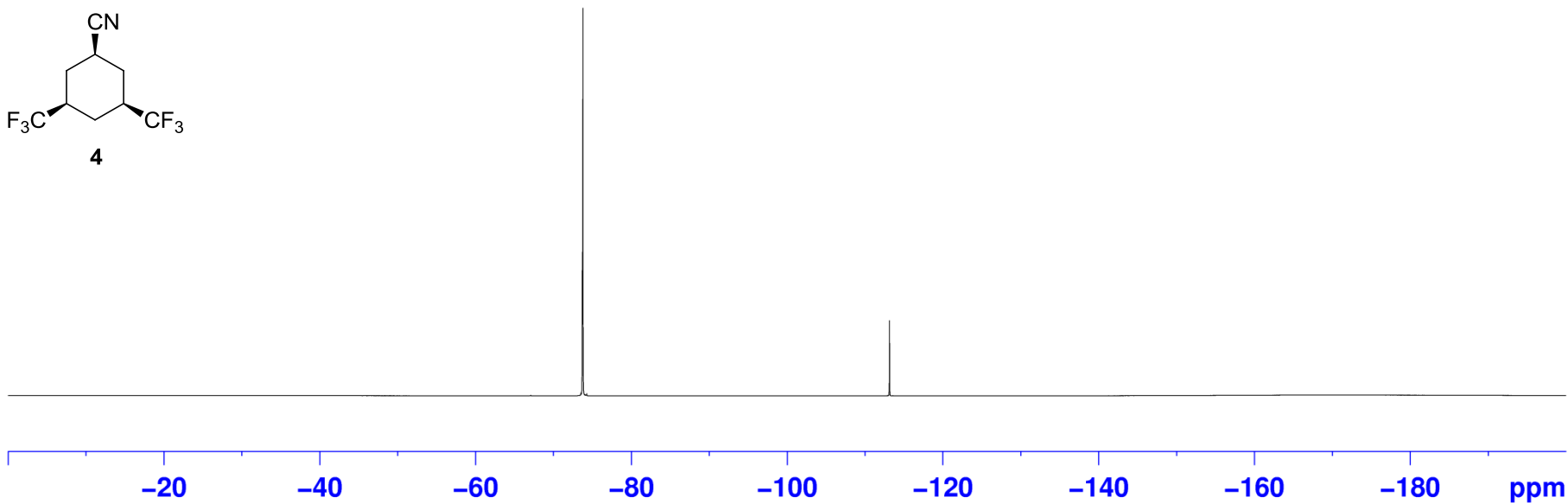
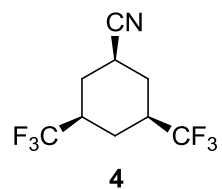
===== CHANNEL f1 =====
SFO1 376.4738882 MHz
NUC1 19F
P1 14.00 usec
PLW1 17.98900032 W

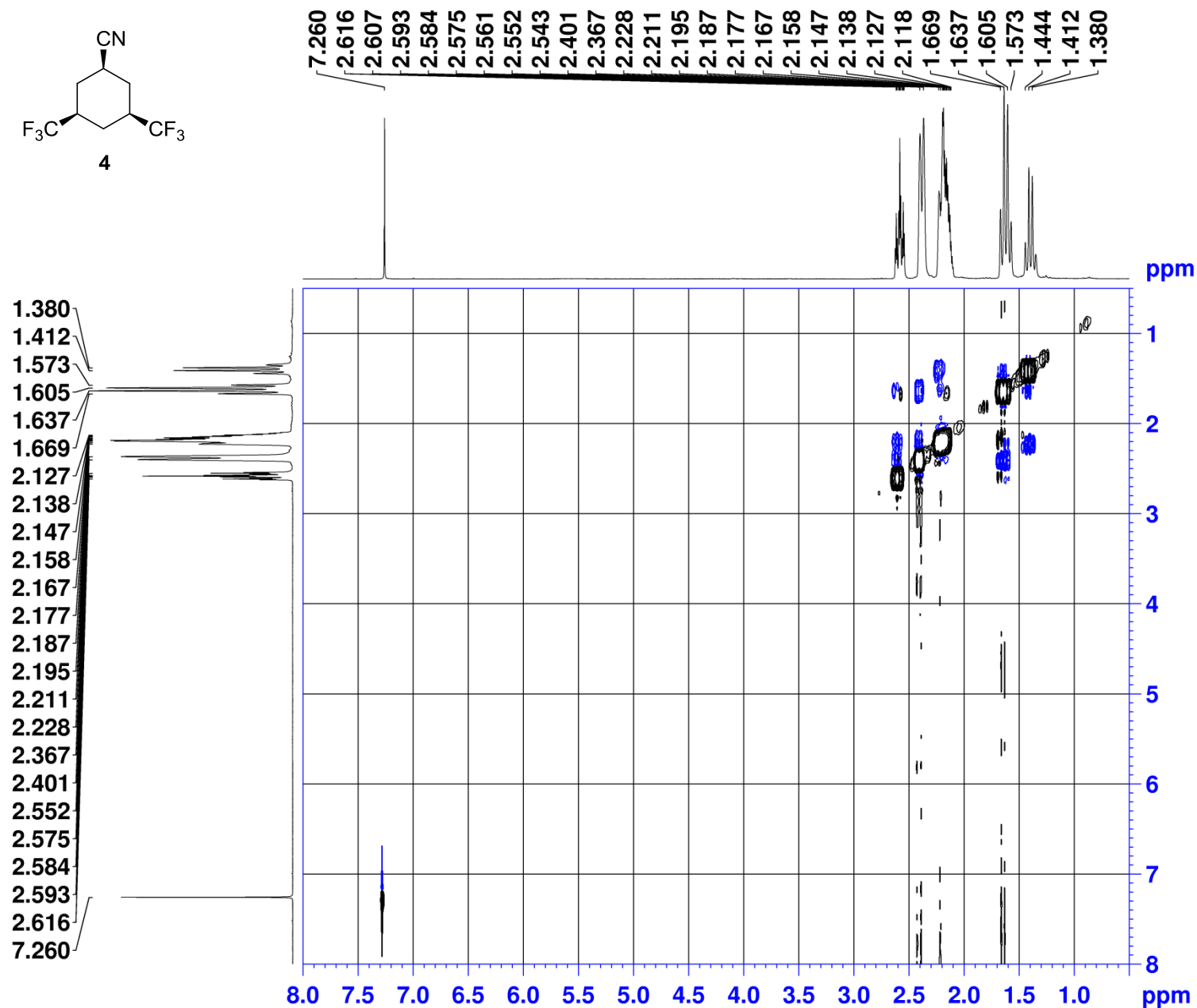
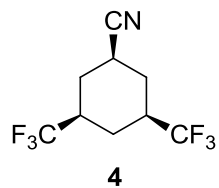
===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG[2] waltz16
PCPD2 90.00 usec
PLW2 11.99499989 W
PLW12 0.34439000 W

F2 - Processing parameters
SI 131072
SF 376.5115146 MHz
WDW EM
SSB 0
LB 5.00 Hz
GB 0
PC 1.00

— -73.79

— -113.15





Current Data Parameters
 NAME kl-1-161-HNOESY
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20160212
 Time 19.10
 INSTRUM spect
 PROBHD 5 mm FABBO BB/
 PULPROG noesygpphps
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 32
 SWH 4084.967 Hz
 FIDRES 1.994613 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 D0 0.00010330 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec

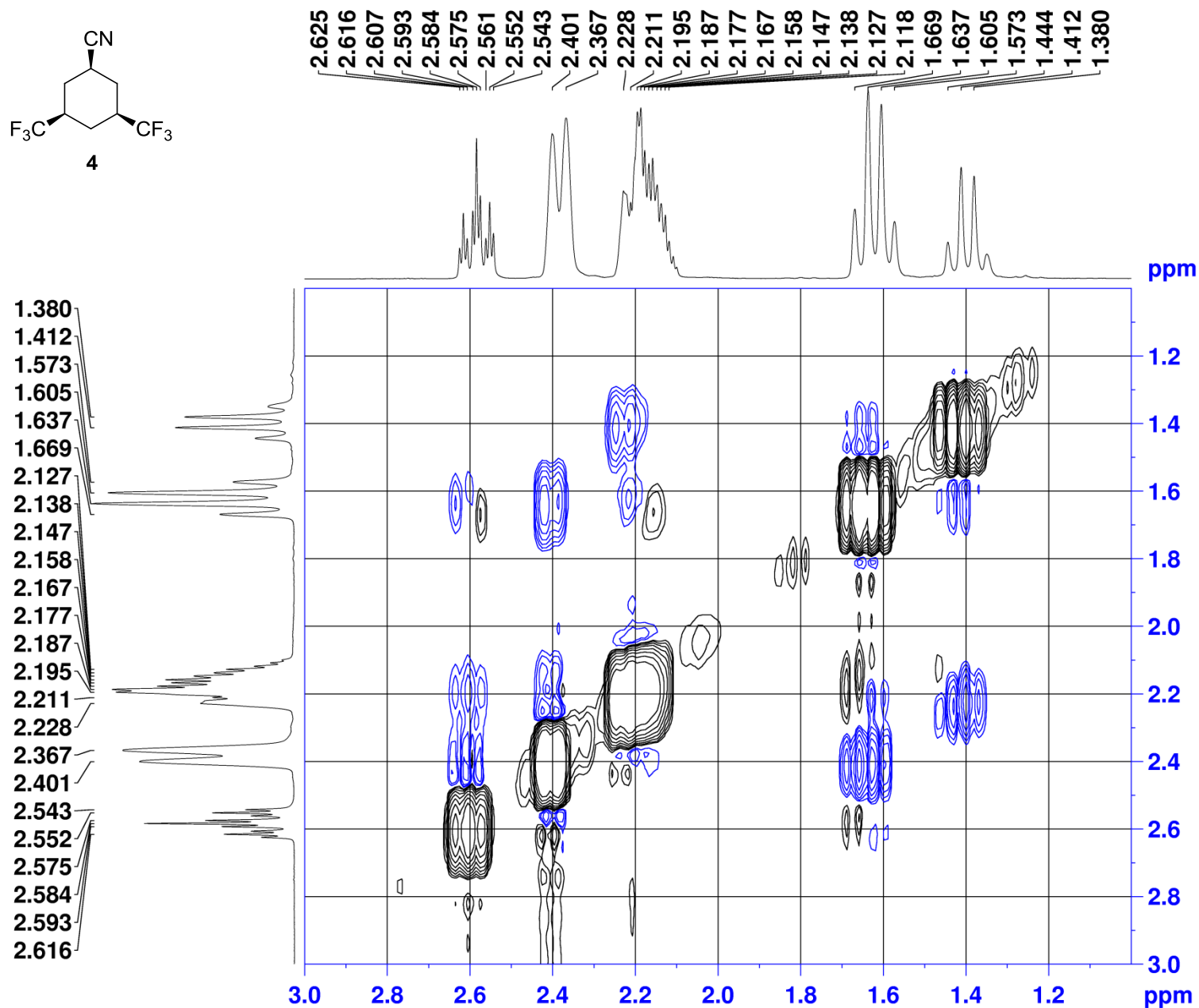
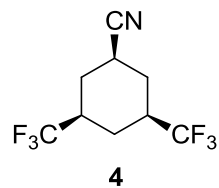
===== CHANNEL f1 =====
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.00 usec
 P2 30.00 usec
 P17 2500.00 usec
 PLW1 12.00000000 W
 PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 165
 SFO1 400.1458 MHz
 FIDRES 24.757378 Hz
 SW 10.209 ppm
 FnmODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0



Current Data Parameters
NAME k1-161-HNOCY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160212
Time 19.10
INSTRUM spect
PROBHD 5 mm FABBO BB/
PULPROG noesygpphps
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
DO 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

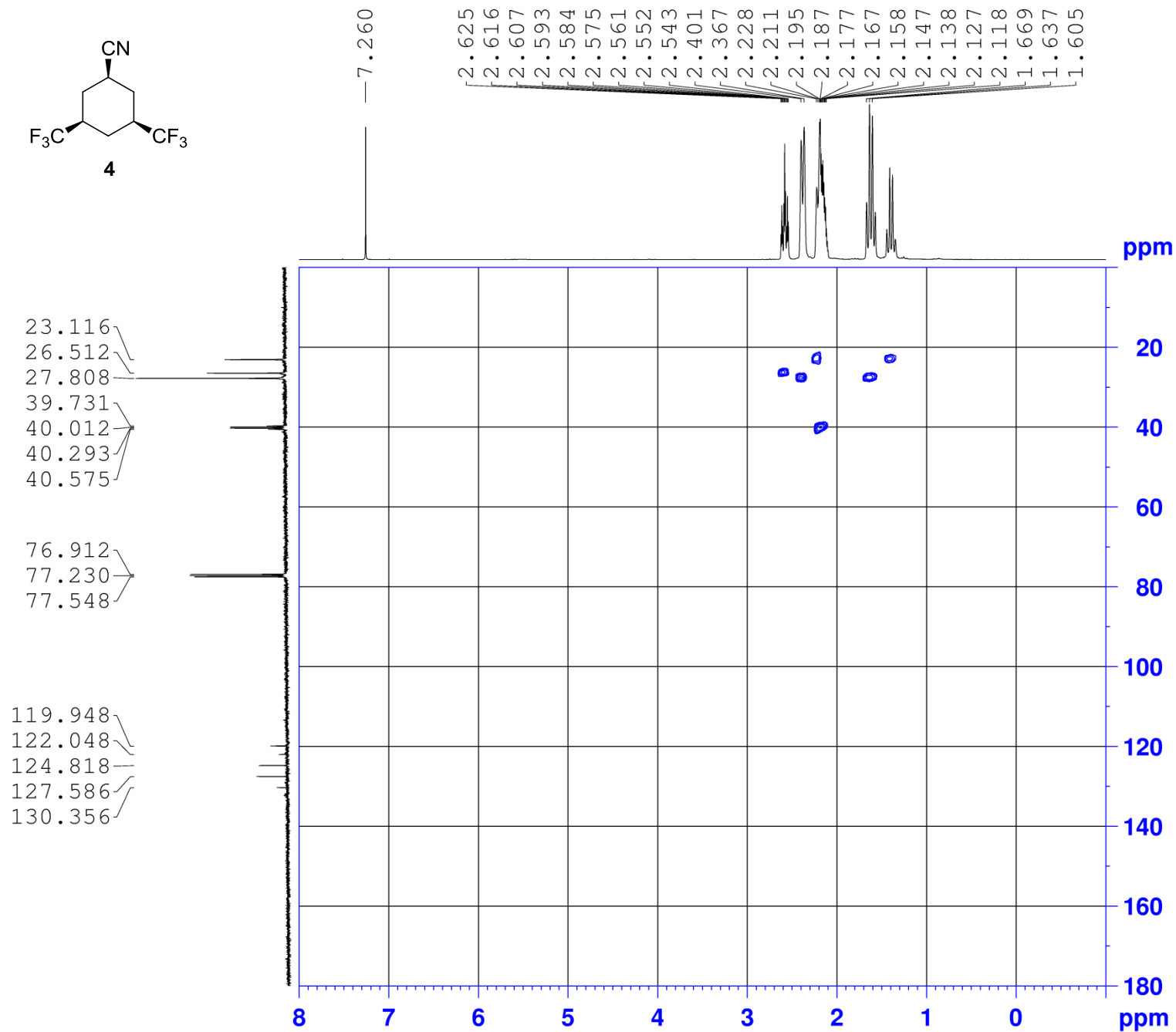
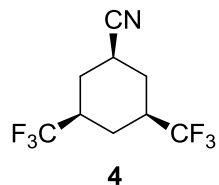
===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 165
SFO1 400.1458 MHz
FIDRES 24.757378 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0



Current Data Parameters
NAME k1-1-161-HSQC
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160212
Time 19.45
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG haqcetdtpslsp2.3
TD 1024
SOLVENT CDCl3
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNS12 145.000000
CNS117 -0.500000
D0 0.00000300 sec
D1 1.50000000 sec
D4 0.0012414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.00360000 sec
D24 0.00089000 sec
INO 0.00003010 sec

===== CHANNEL f1 =====
SFO1 400.1458807 MHz
NUC1 1H
P1 15.25 usec
P2 30.50 usec
P28 1000.00 usec
PLW1 12.00000000 W

===== CHANNEL f2 =====
SFO2 100.623320 MHz
NUC2 13C
CPDPRG2 bi_p5m4p4ap-2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1900.00 usec
P63 1500.00 usec
PLW2 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SPOAL3 0.500
SPOFS3 0 Hz
SPW3 7.63940001 W
SPNAM[7] Crp60comp,4
SPOAL7 0.500
SPOFS7 0 Hz
SPW7 7.63940001 W
SPNAM[14] Crp32,1.5,20.2
SPOAL14 0.500
SPOFS14 0 Hz
SPW14 3.25950003 W
SPNAM[18] Crp60_xf11c,2
SPOAL18 0.500
SPOFS18 0 Hz
SPW18 1.83050001 W
SPNAM[31] Crp32,1.5,20.2
SPOAL31 0.500
SPOFS31 0 Hz
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPNAM[3] SMSQ10.100
GPNAM[4] SMSQ10.100
GP21 80.00 %
GP22 20.10 %
GP23 11.00 %
GP24 -5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 65
SFO1 100.6233 MHz
FIDRES 255.558395 Hz
SW 165.084 ppm
FMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.612890 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0



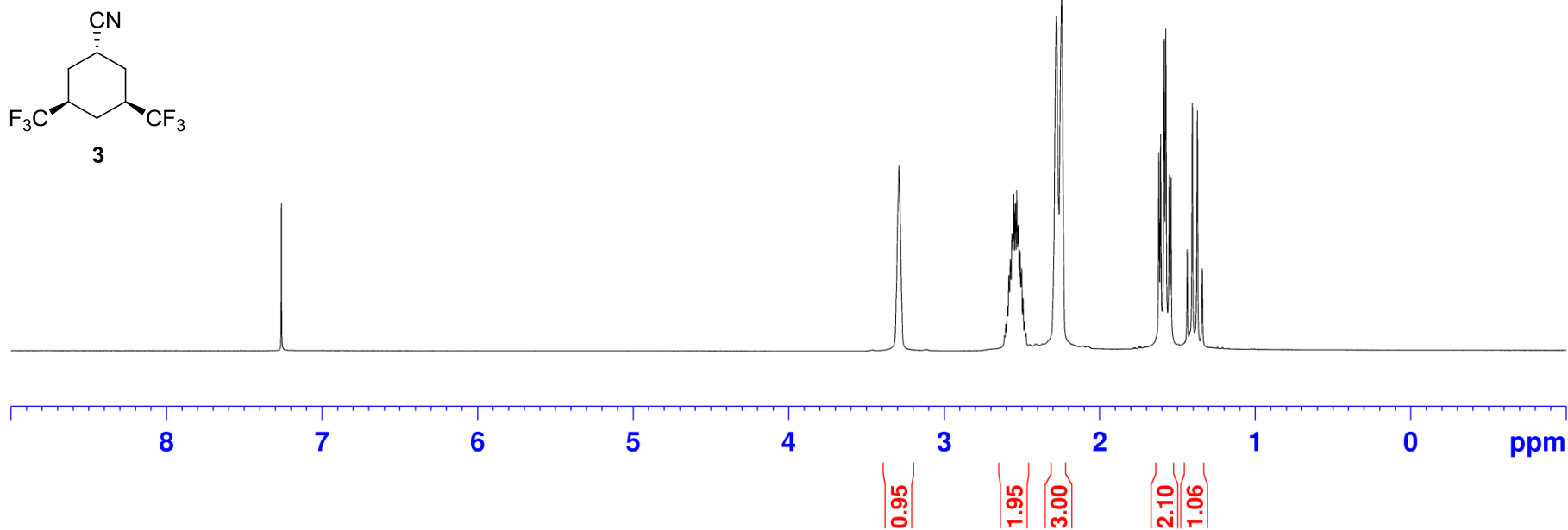
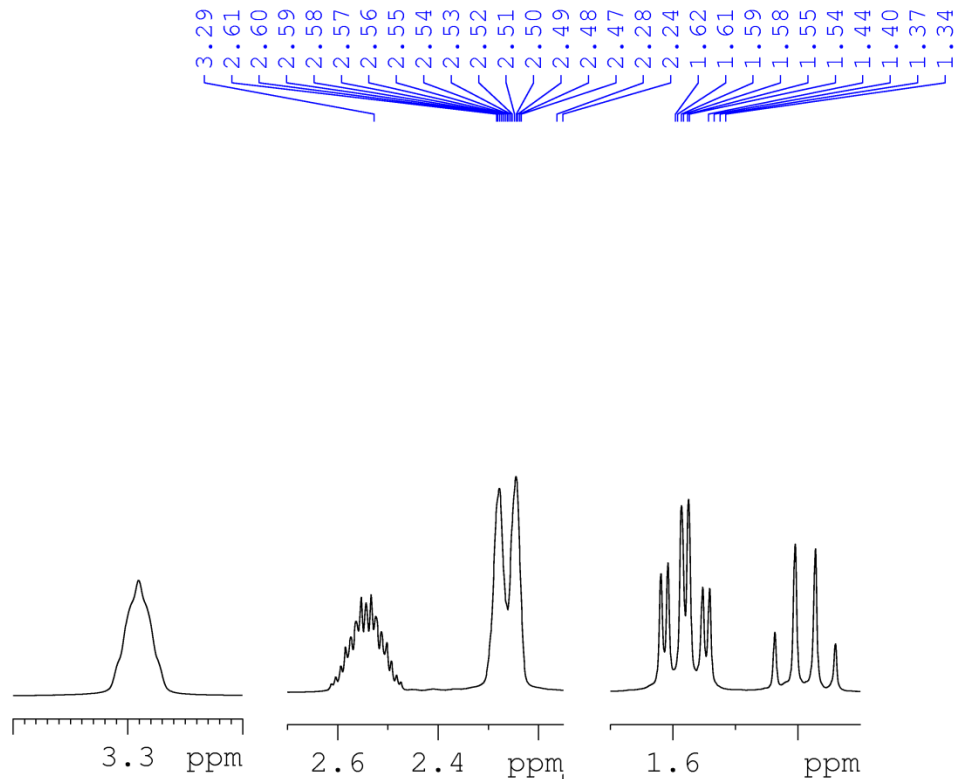
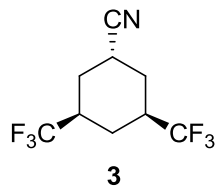
— 7.26

Current Data Parameters
NAME kl-1-161-Axial-1H
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160628
Time 19.18
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 32768
SOLVENT CDC13
NS 32
DS 2
SWH 7211.539 Hz
FIDRES 0.220079 Hz
AQ 2.2719147 sec
RG 90.5
DW 69.333 usec
DE 6.50 usec
TE 300.0 K
D1 0.50000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 32768
SF 400.1440093 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00





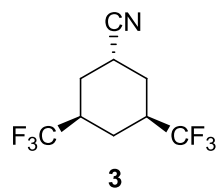
Current Data Parameters
NAME k1-2-161-Akial-13C
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160628
Time 20.45
INSTRUM spect
PROBHD 5 mm PARBO BB/
PULPROG udefc
TD 17388
SOLVENT CDCl3
NS 976
DS 0
SWH 24038.461 Hz
FIDRES 1.388864 Hz
AQ 0.3600064 sec
RG 203
RW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 4.00000000 sec
D11 0.03000000 sec
D12 0.00000000 sec
D20 200.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6273568 MHz
NUC1 13C
P1 10.00 usec
P13 2000.00 usec
P26 500.00 usec
PLW1 50.00299835 W
SPNAM[5] Crp60comp.4
SFOAL5 0 Hz
SFOFF5 0 Hz
SPW5 7.63990021 W
SPNAM[8] Crp60,0.5,20.1
SFOAL8 0.500
SFOFF8 0 Hz
SPW8 7.63990021 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPCPRG[2] waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W

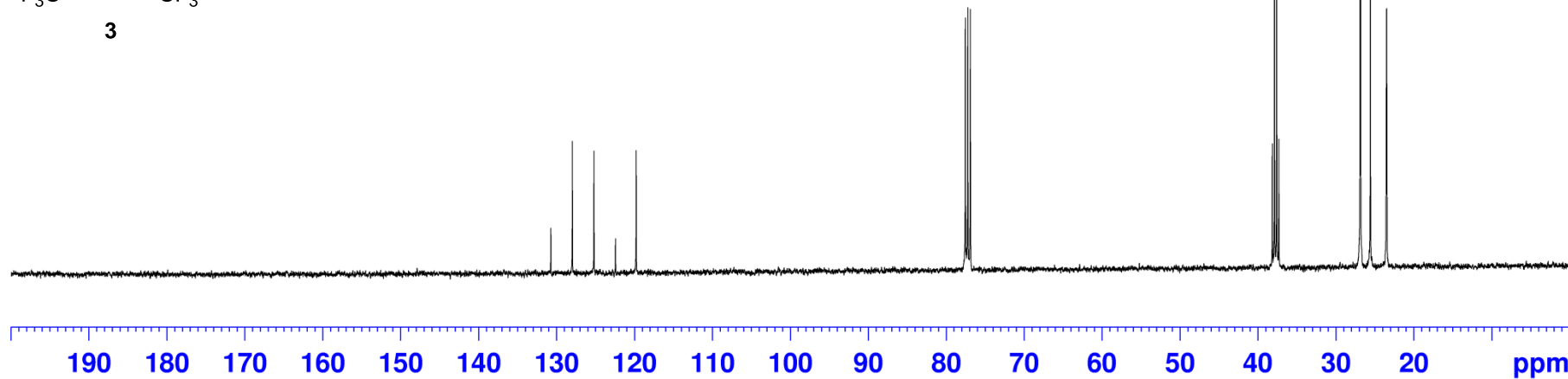
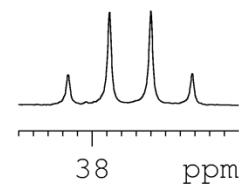
F2 - Processing parameters
SI 131072
SF 100.6162676 MHz
WDW EM
SSB 0
LB 2.00 Hz
GB 0
PC 1.40



— 130.74
— 127.97
— 125.20
— 122.44
— 119.79

77.55
77.23
76.91

38.16
37.88
37.60
37.32
26.90
26.87
26.85
26.82
25.58
23.58
23.55
23.53
23.50
23.48
23.44
23.41





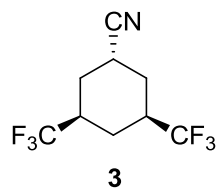
Current Data Parameters
NAME kl-1-161-Axial-19F
EXPHO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160628
Time 23.02
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgfhqgn.2
TD 131072
SOLVENT CDCl3
NS 15
DS 4
SWH 89285.711 Hz
FIDRES 0.681196 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 3.00000000 sec
D11 0.03000000 sec
D12 0.00002000 sec
TDO 1

===== CHANNEL f1 =====
SFO1 376.4738882 MHz
NUC1 19F
P1 14.00 usec
PLW1 17.98900032 W

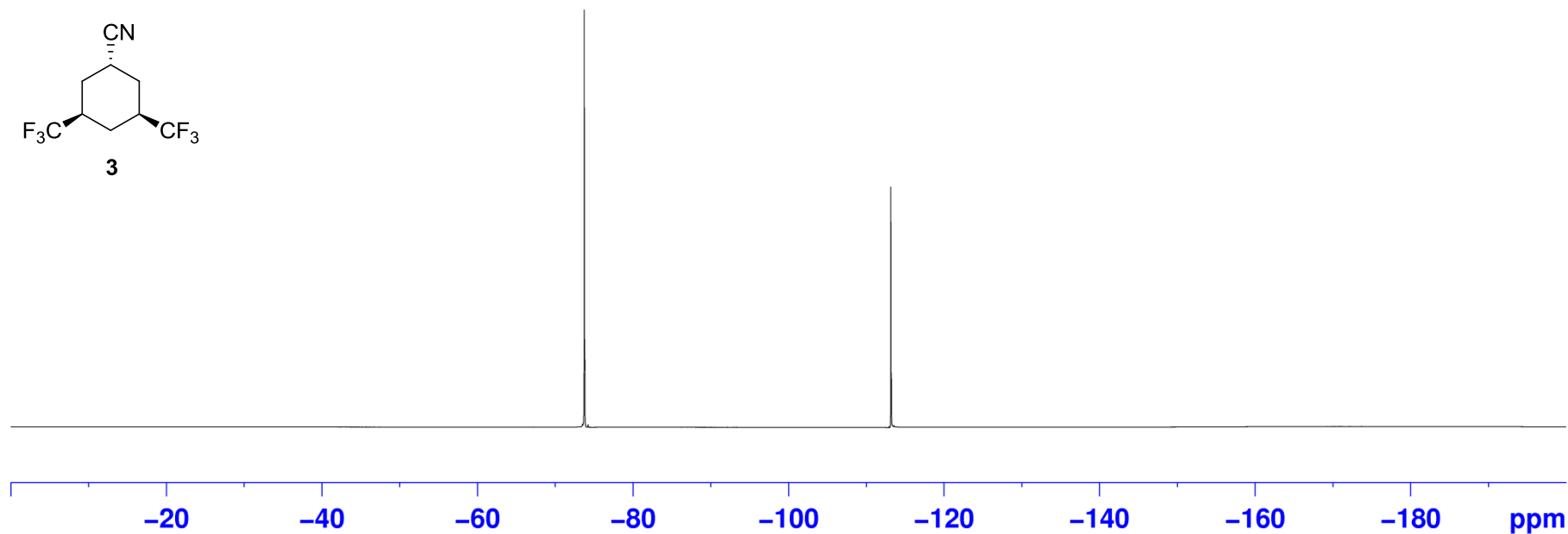
===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG[2] waltz16
PCPD2 90.00 usec
PLW2 11.99499989 W
PLW12 0.34439000 W

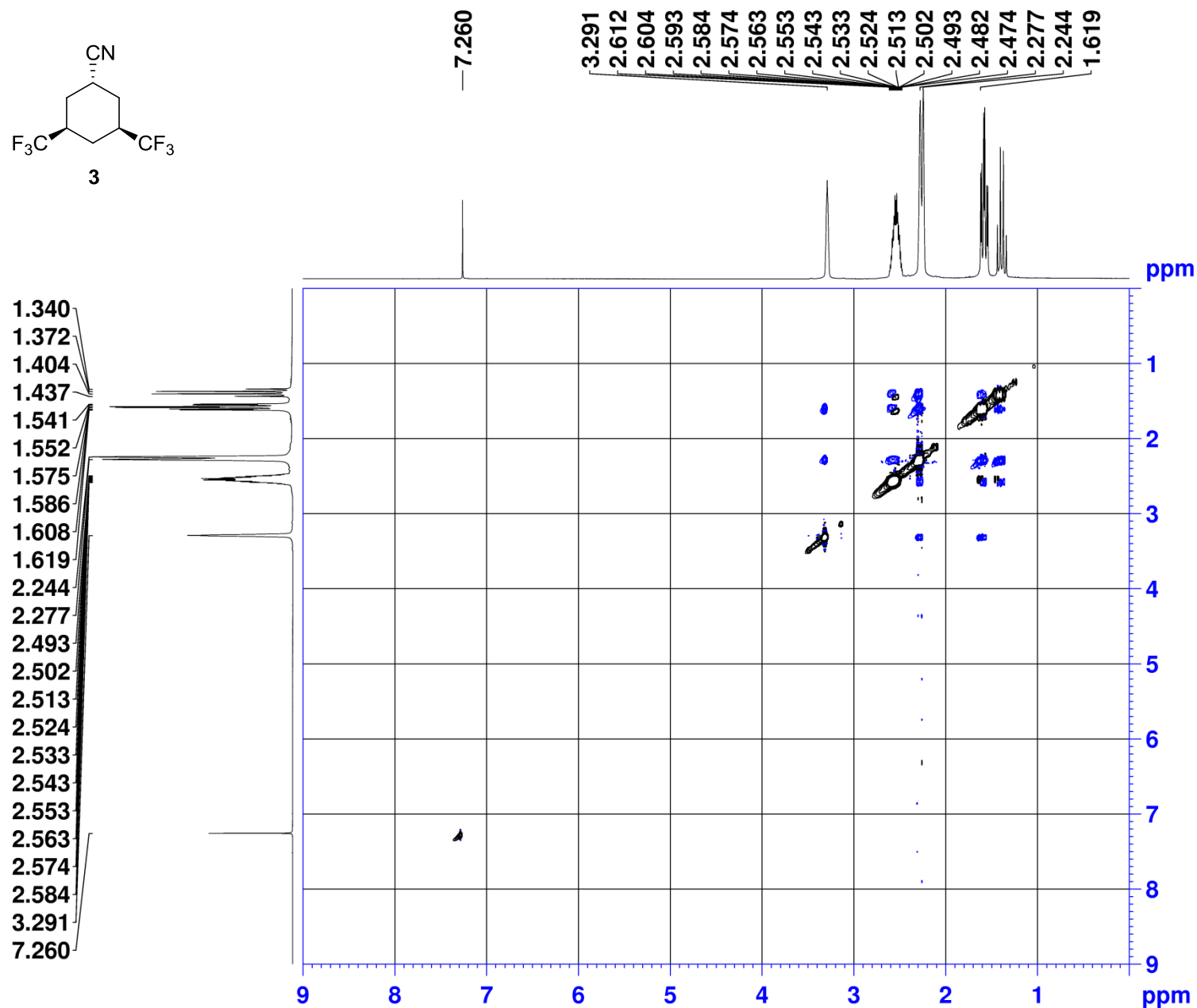
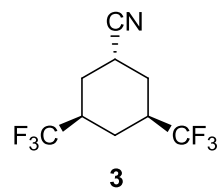
F2 - Processing parameters
SI 131072
SF 376.5115513 MHz
WDW EM
SSB 0
LB 5.00 Hz
GB 0
PC 1.00



— -73.72

— -113.15





Current Data Parameters
 NAME kl-1-161-Axial-HNOESY
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20160628
 Time 21.10
 INSTRUM spect
 PROBHD 5 mm FABBO BB/
 PULPROG noesygpphpg
 TD 2048
 SOLVENT CDCl₃
 NS 4
 DS 16
 SWH 4084.967 Hz
 FIDRES 1.994613 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 D0 0.00010266 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec

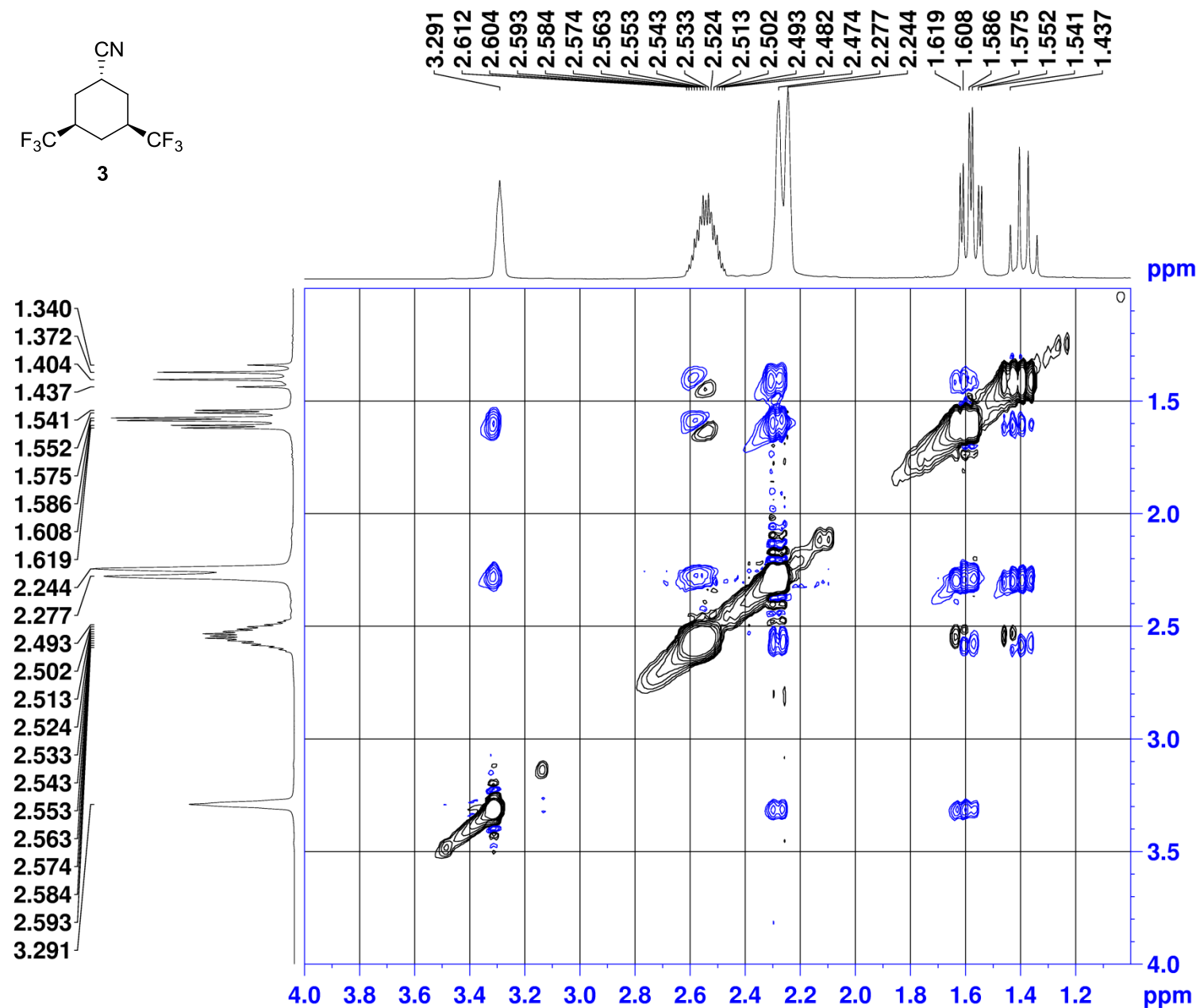
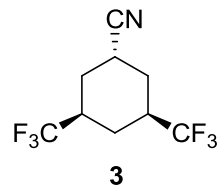
===== CHANNEL f1 =====
 SF01 400.1458419 MHz
 NUC1 1H
 P1 15.50 usec
 P2 31.00 usec
 P17 2500.00 usec
 PLW1 11.99499989 W
 PLW10 4.26300001 W

===== GRADIENT CHANNEL =====
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SF01 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FnmODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0



Current Data Parameters
 NAME kl-1-i61-Axial-HNOESY
 EXPNO 1
 PROCNO 1

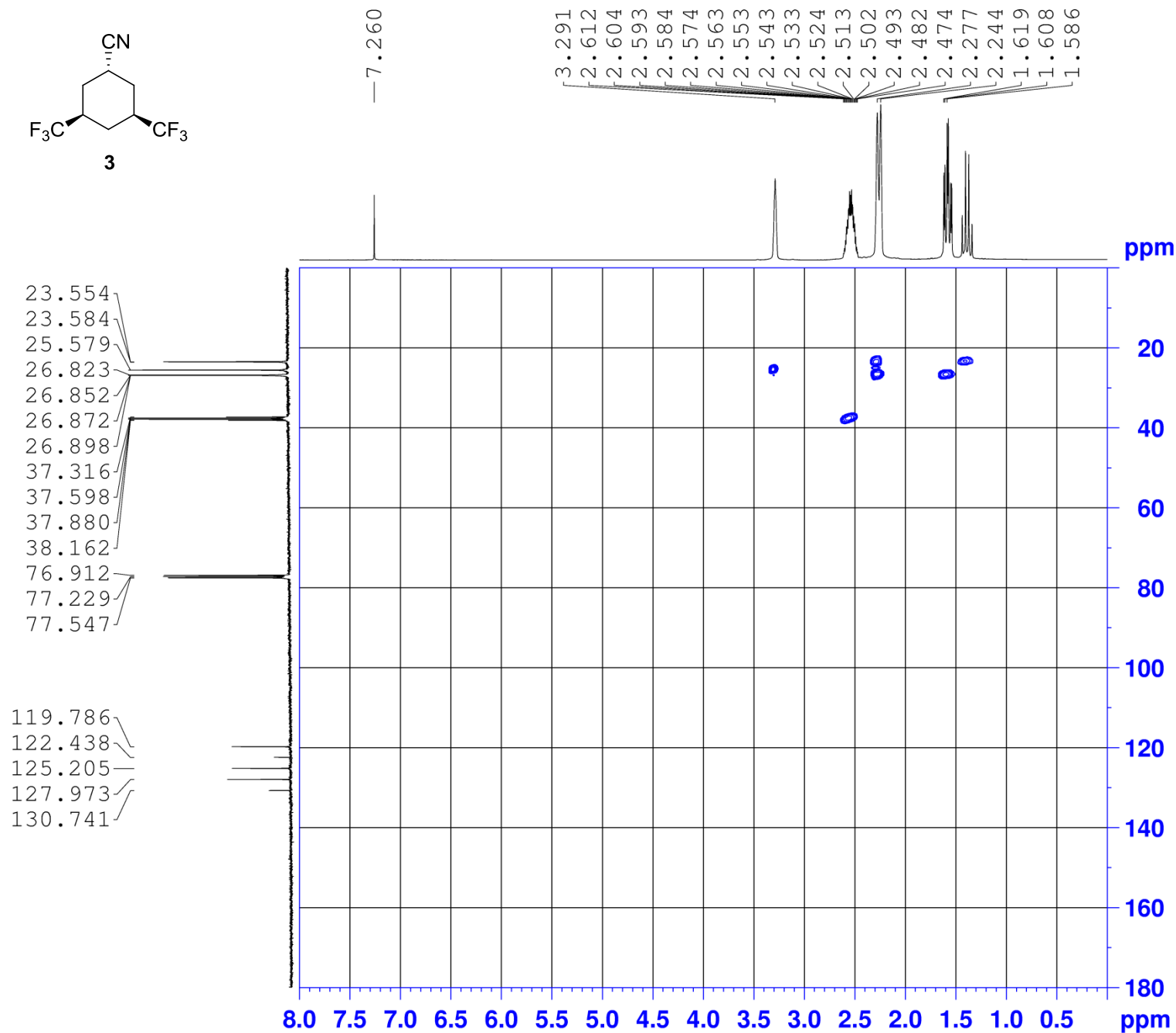
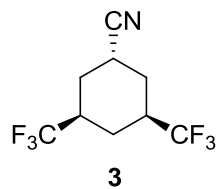
F2 - Acquisition Parameters
 Date_ 20160628
 Time 21.10
 INSTRUM spect
 PROBHD 5 mm FABBO BB/
 PULPROG noesygpgppp
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 16
 SWH 4084.967 Hz
 FIDRES 1.994613 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 D0 0.00010266 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec

===== CHANNEL f1 =====
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.50 usec
 P2 31.00 usec
 P17 2500.00 usec
 PLW1 11.99499989 W
 PLW10 4.26300001 W
 ===== GRADIENT CHANNEL =====
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FnmODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0



Current Data Parameters
NAME: K1-1-161-Axial-HSQC
EXPNO: 1
PROCNO: 1

F2 - Acquisition Parameters
Date_: 20160628
Time: 20.48
INSTRUM: spect
PROBHD: 5 mm PABBO BB/
PULPROG: hsqcetdcp1sp2.3
TD: 1024
SOLVENT: CDCl3
NS: 4
DS: 16
SWH: 6410.256 Hz
FIDRES: 6.260016 Hz
AQ: 0.0798720 sec
RG: 203
DW: 78.000 usec
DE: 6.50 usec
TE: 300.0 K
CNS12: 145.000000
CNS117: -0.500000
D0: 0.00000300 sec
D1: 1.50000000 sec
D4: 0.0012414 sec
D11: 0.03000000 sec
D16: 0.00020000 sec
D21: 0.00360000 sec
D24: 0.00089000 sec
INO: 0.00003010 sec

===== CHANNEL f1 =====
SFO1: 400.1458807 MHz
NUC1: 1H
P1: 15.25 usec
P2: 30.50 usec
P18: 1000.00 usec
P1W1: 12.00000000 W

===== CHANNEL f2 =====
SFO2: 100.623320 MHz
NUC2: 13C
CPDPRG2: bi_p5m4p4p-2
P3: 10.00 usec
P14: 500.00 usec
P24: 2000.00 usec
P31: 1800.00 usec
P63: 1500.00 usec
P1W2: 0 W
P1W3: 50.00000000 W
P1W12: 0.78125000 W
SPNAM[3]: Crp60,0.5,20.1
SPOAL3: 0.500
SPOFS3: 0 Hz
SPW3: 7.63940001 W
SPNAM[7]: Crp60comp,4
SPOAL7: 0.500
SPOFS7: 0 Hz
SPW7: 7.63940001 W
SPNAM[14]: Crp32,1.5,20.2
SPOAL14: 0.500
SPOFS14: 0 Hz
SPW14: 3.25950003 W
SPNAM[18]: Crp60_xf11c,2
SPOAL18: 0.500
SPOFS18: 0 Hz
SPW18: 1.83050001 W
SPNAM[31]: Crp32,1.5,20.2
SPOAL31: 0.500
SPOFS31: 0 Hz
SPW31: 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1]: SMSQ10.100
GPNAM[2]: SMSQ10.100
GPNAM[3]: SMSQ10.100
GPNAM[4]: SMSQ10.100
GP21: 80.00 %
GP22: 20.10 %
GP23: 11.00 %
GP24: -5.00 %
P16: 1000.00 usec
P19: 600.00 usec

F1 - Acquisition parameters
TD: 128
SFO1: 100.6233 MHz
FIDRES: 129.775742 Hz
SW: 165.084 ppm
FMODE: Echo-Antiecho

F2 - Processing parameters
SI: 1024
SF: 400.1440000 MHz
WDW: QSINE
SSB: 2
LB: 0 Hz
GB: 0
PC: 1.40

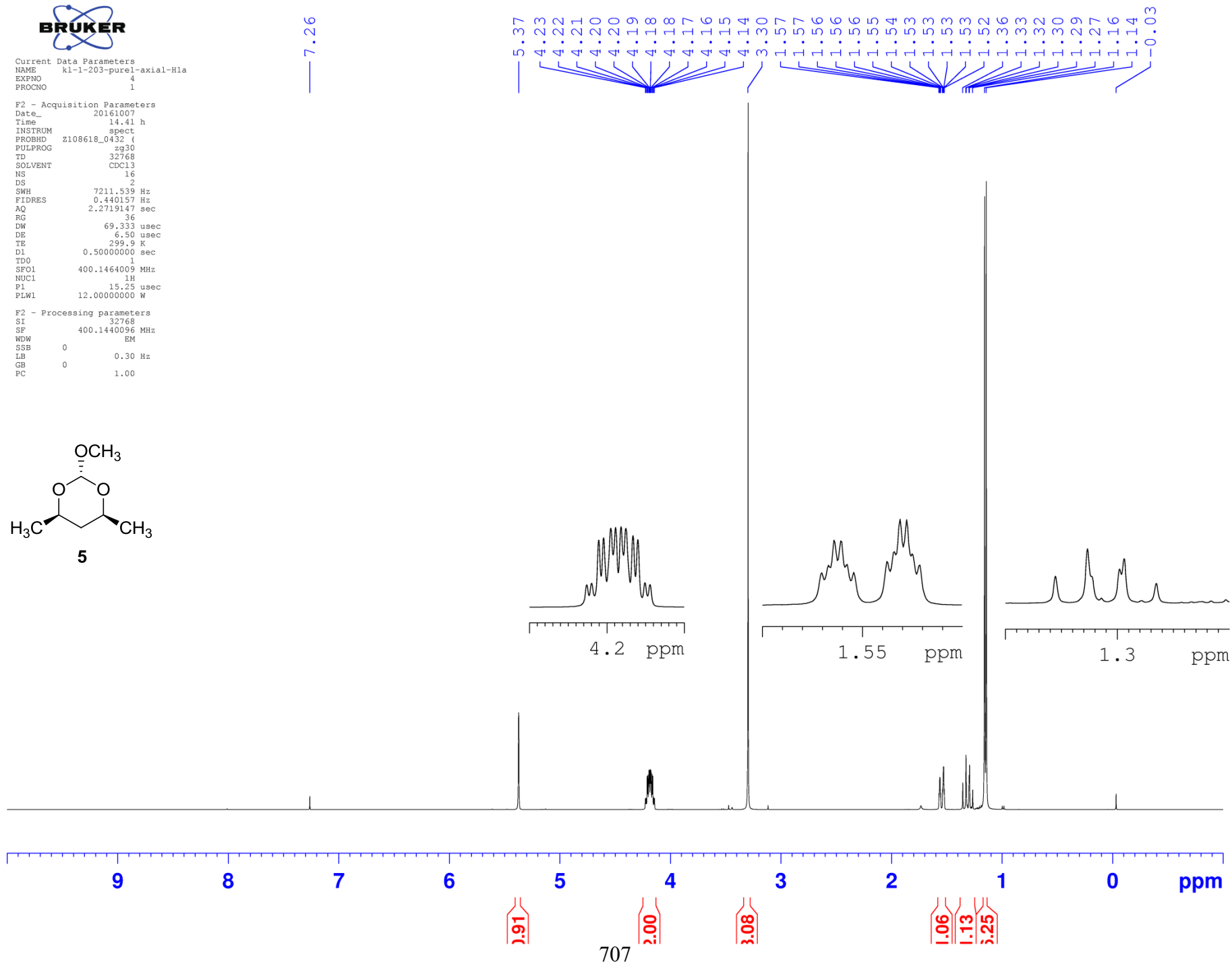
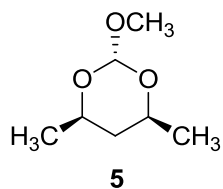
F1 - Processing parameters
SI: 1024
MC2: echo-antiecho
SF: 100.612890 MHz
WDW: QSINE
SSB: 2
LB: 0 Hz
GB: 0



Current Data Parameters
NAME kl-1-203-pure1-axial-H1a
EXPNO 4
PROCNO 1

F2 - Acquisition Parameters
Date_ 20161007
Time 14.41 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zg30
TD 32768
SOLVENT CDCl3
NS 16
DS 2
SWH 7211.539 Hz
FIDRES 0.440157 Hz
AQ 2.2719147 sec
RG 36
DW 69.333 usec
DE 6.50 usec
TE 299.9 K
D1 0.5000000 sec
TD0 1
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 32768
SF 400.1440096 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

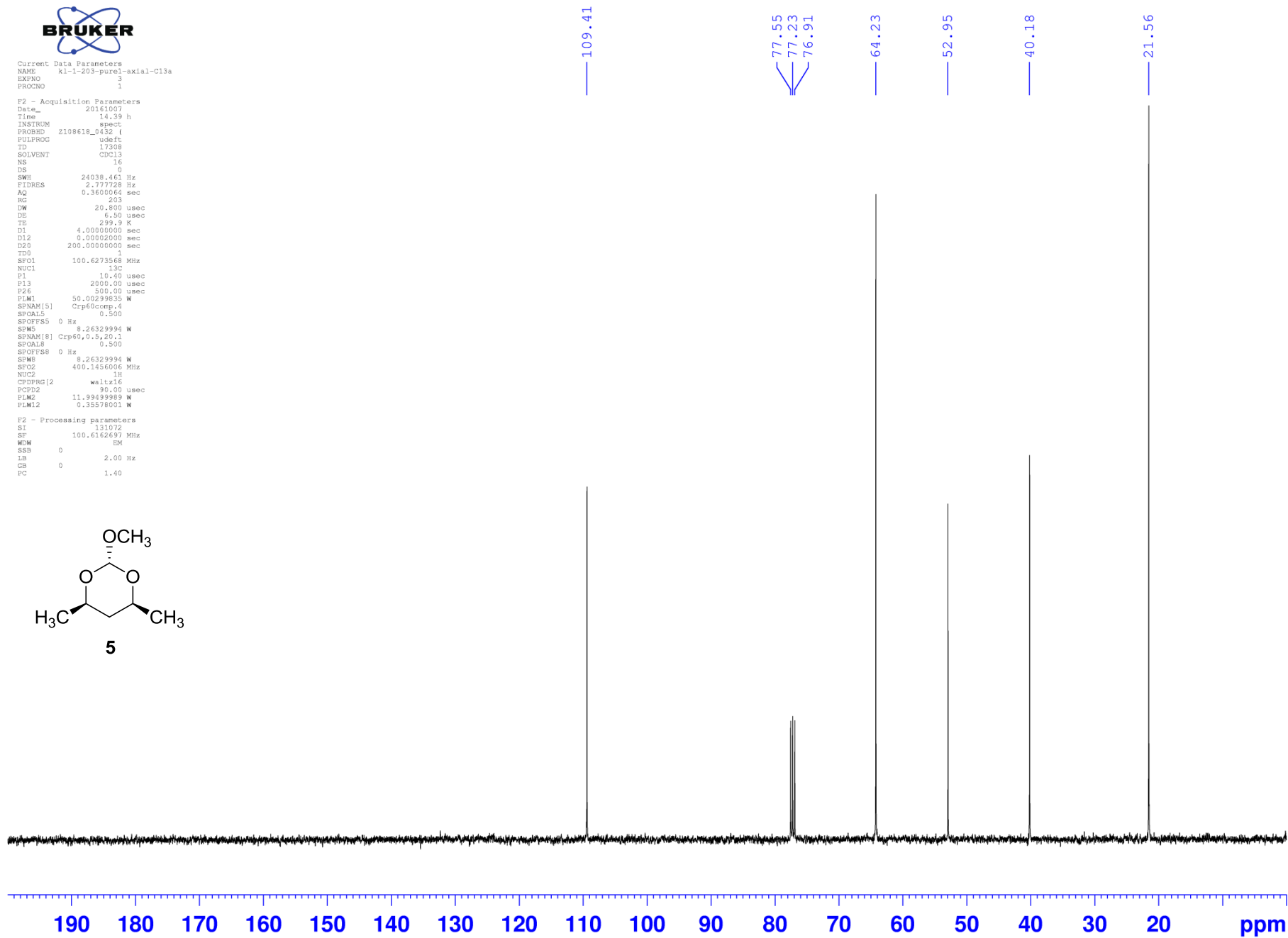
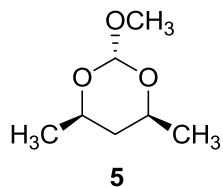




Current Data Parameters
NAME: k1-1-203-pure1-axial-C13a
EXPNO: 3
PROCNO: 1

F2 - Acquisition Parameters
Date_: 20161007
Time: 14:39 h
INSTRUM: spect
PROBHD: z108618_0432 (4
PULPROG: udeft
TD: 17308
SOLVENT: CDCl3
NS: 16
DS: 0
SWH: 24038.461 Hz
FIDRES: 2.777728 Hz
AQ: 0.3600064 sec
RG: 203
DW: 20.600 usec
DE: 6.50 usec
TE: 299.9 K
D1: 4.00000000 sec
D12: 0.00002000 sec
D20: 200.00000000 sec
TD0: 1
SFO1: 100.6273568 MHz
NUC1: 13C
P1: 10.40 usec
P13: 2000.00 usec
P26: 500.00 usec
PLW1: 50.00299835 W
SPNAM[5]: Crp60comp.4
SPCAL5: 0.500
SPOFF5: 0 Hz
SPW5: 8.26329994 W
SPNAM[9]: Crp60,0.5,20.1
SPOFF6: 0.500
SPOFF8: 0 Hz
SPW6: 8.26329994 W
SFO2: 400.1456006 MHz
NUC2: 1H
CPDPRG2: waltz16
PCPD2: 90.00 usec
PLW2: 11.99499989 W
PLW12: 0.35578001 W

F2 - Processing parameters
SI: 131072
SF: 100.6162697 MHz
WDW: EM
SSB: 0
LB: 2.00 Hz
GB: 0
PC: 1.40





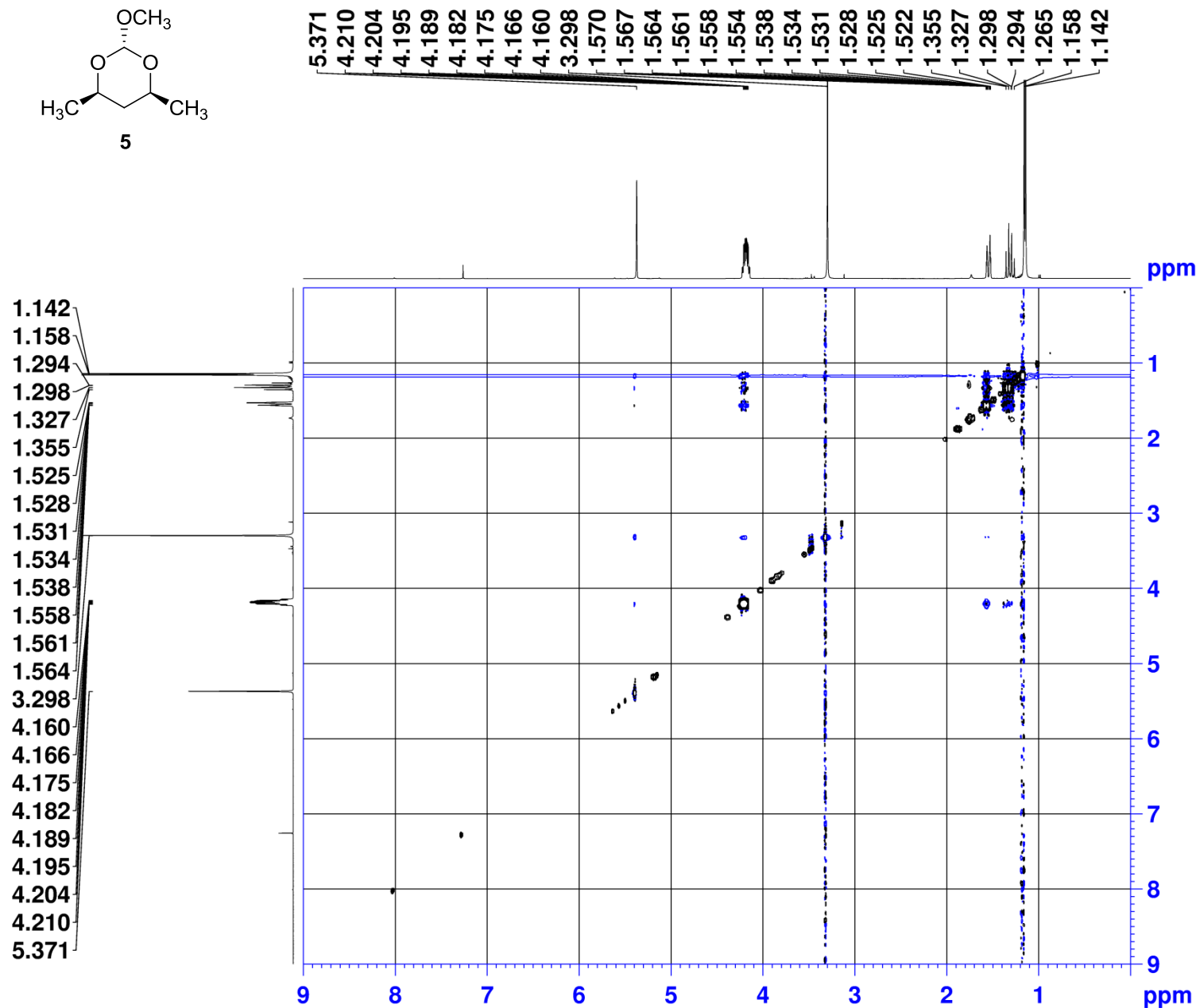
Current Data Parameters
 NAME kl-1-203-HINOSY-Axial
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20161007
 Time 19.11 h
 INSTRUM spect
 PROBHD Z108618_0432 (
 PULPROG noesygpph
 TD 2048
 SOLVENT CDC13
 NS 4
 DS 16
 SWH 4084.967 Hz
 FIDRES 3.989226 Hz
 AQ 0.2506752 sec
 RG 50.8
 DW 122.400 usec
 DE 6.50 usec
 TE 299.9 K
 D0 0.00010266 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec
 TDAV 1
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.50 usec
 P2 31.00 usec
 P17 2500.00 usec
 PLW1 11.99499989 W
 PLW10 4.26300001 W
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FMODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0





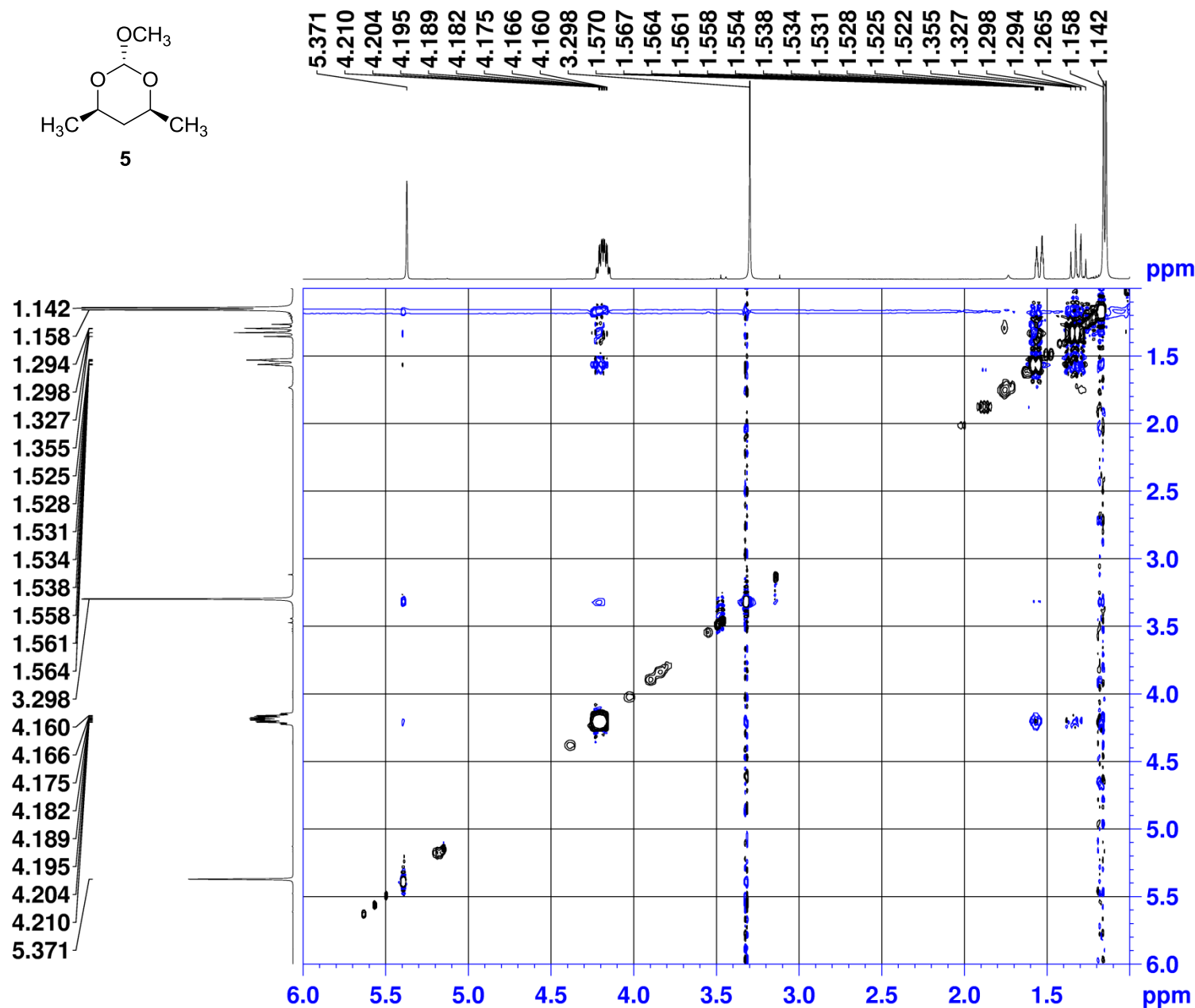
Current Data Parameters
 NAME kl-1-203-H1NOESY-Axial
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20161007
 Time 19.11 h
 INSTRUM spect
 PROBHD Z108618_0432 (
 PULPROG noesygpph
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 16
 SWH 4084.967 Hz
 FIDRES 3.989226 Hz
 AQ 0.2506752 sec
 RG 50.8
 DW 122.400 usec
 DE 6.50 usec
 TE 299.9 K
 D0 0.00010266 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec
 TDAV 1
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.50 usec
 P2 31.00 usec
 P17 2500.00 usec
 PLW1 11.99499989 W
 PLW10 4.26300001 W
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FMODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0

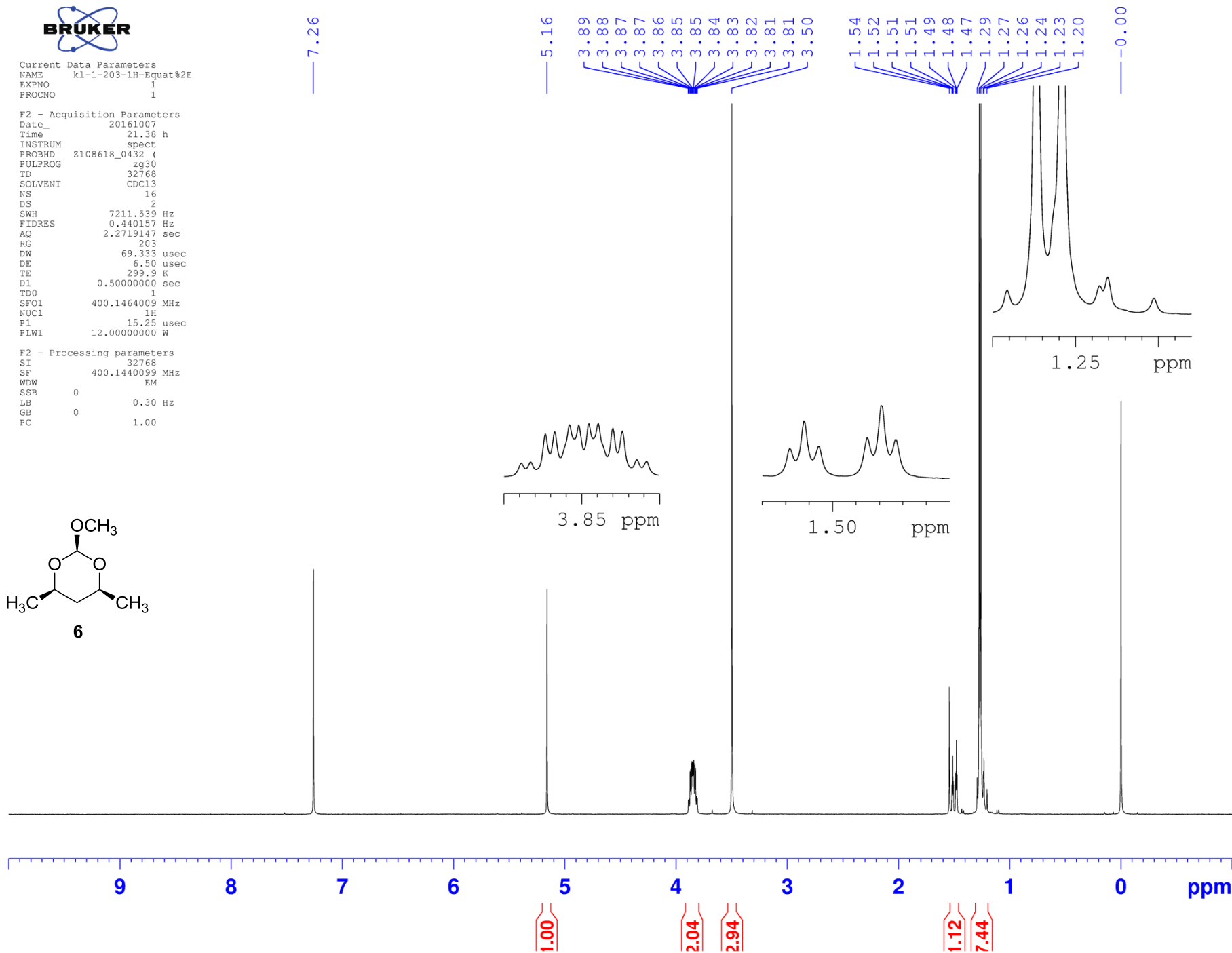
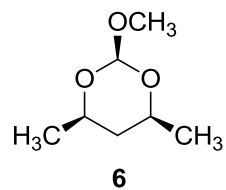




Current Data Parameters
NAME kl-1-203-1H-Equat%2E
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20161007
Time 21.38 h
INSTRUM spect
PROBHD z108618_0432 (
PULPROG zg30
TD 32768
SOLVENT CDC13
NS 16
DS 2
SWH 7211.539 Hz
FIDRES 0.440157 Hz
AQ 2.2719147 sec
RG 203
DW 69.333 usec
DE 6.50 usec
TE 299.9 K
D1 0.50000000 sec
TD0 1
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 32768
SF 400.1440099 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

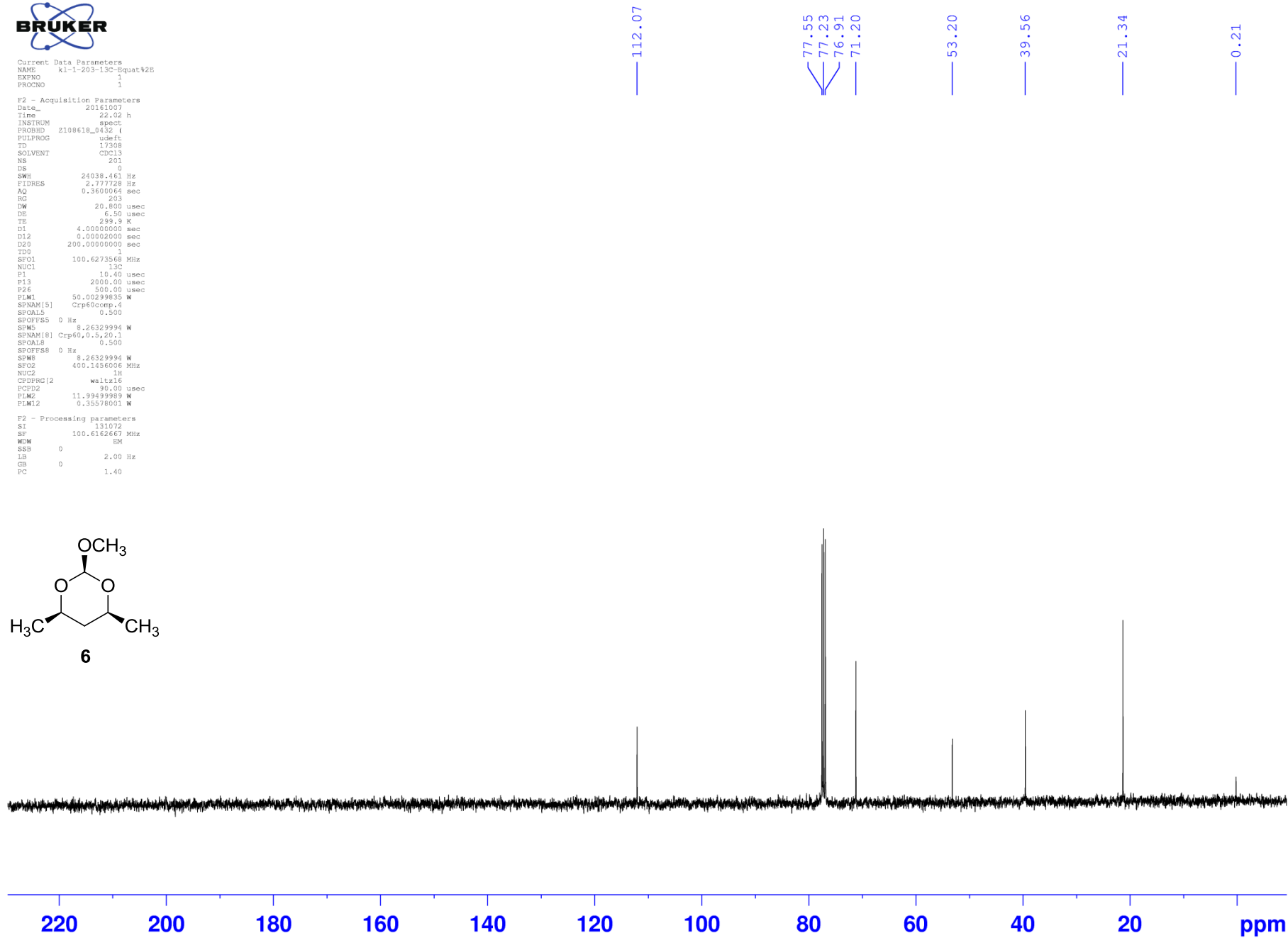
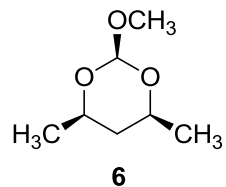




Current Data Parameters
NAME: k1-1-203-13C-Equat2E
EXPNO: 1
PROCNO: 1

F2 - Acquisition Parameters
Date_: 20161007
Time: 22.02 h
INSTRUM: spect
PROBHD: z108618_0432 (4
PULPROG: udeft
TD: 17308
SOLVENT: CDCl3
NS: 201
DS: 0
SWH: 24038.461 Hz
FIDRES: 2.777728 Hz
AQ: 0.3600064 sec
RG: 203
DW: 20.600 usec
DE: 6.50 usec
TE: 299.9 K
D1: 4.00000000 sec
D12: 0.00002000 sec
D20: 200.00000000 sec
TD0: 1
SFO1: 100.6273568 MHz
NUC1: 13C
P1: 10.40 usec
P13: 2000.00 usec
P26: 500.00 usec
PLW1: 50.00299835 W
SPNAM[5]: Crp60comp.4
SPCAL5: 0.500
SPOFFS5: 0 Hz
SPW5: 8.26329994 W
SPNAM[9]: Crp60,0.5,20.1
SPOKL6: 0.500
SPOFFS8: 0 Hz
SPW8: 8.26329994 W
SFO2: 400.1456006 MHz
NUC2: 1H
CPDPRG[2]: waltz16
PCPD2: 90.00 usec
PLW2: 11.99499989 W
PLW12: 0.35578001 W

F2 - Processing parameters
SI: 131072
SF: 100.6162467 MHz
WDW: EM
SSB: 0
LB: 2.00 Hz
GB: 0
PC: 1.40





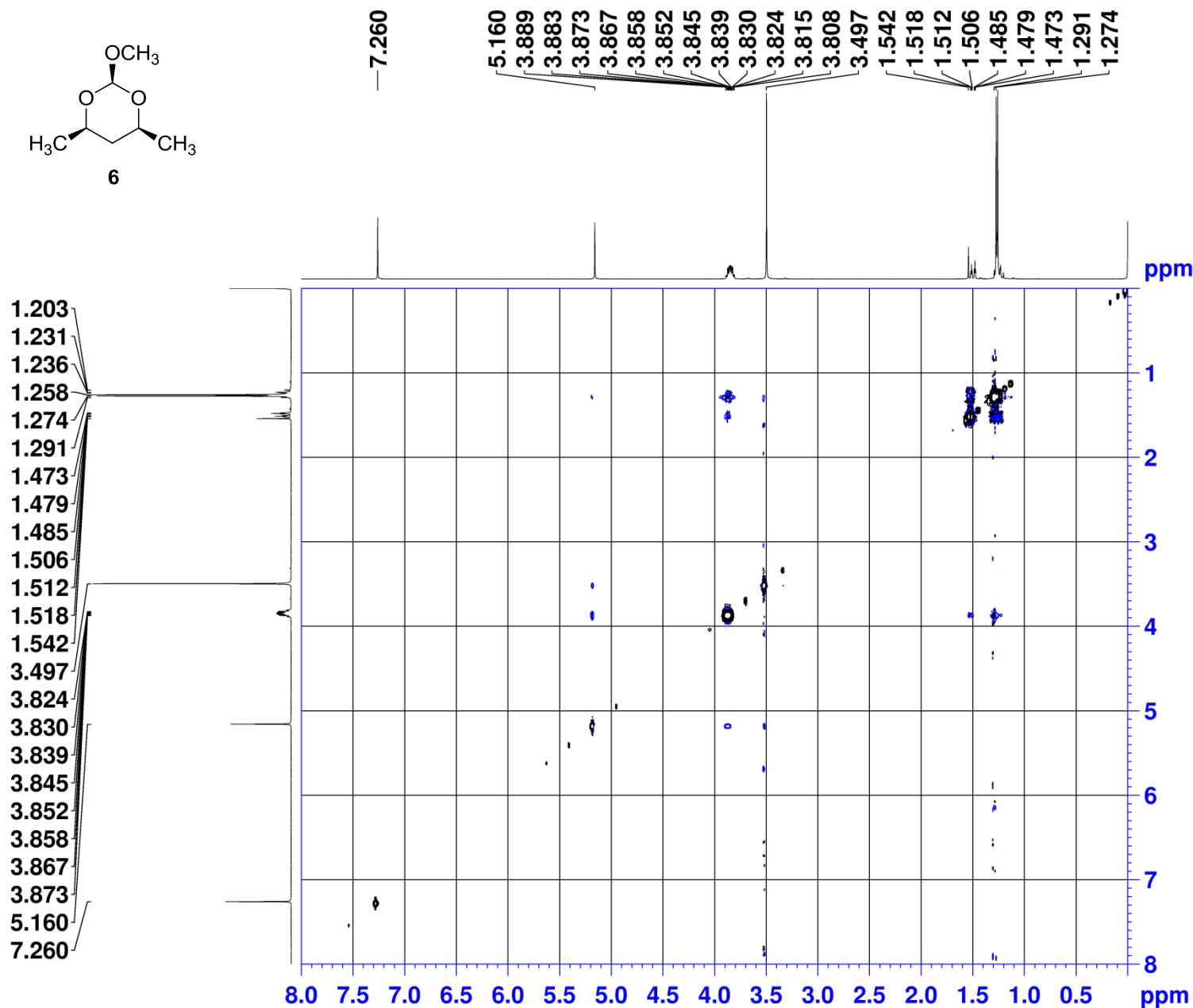
Current Data Parameters
 NAME kl-1-203-HNOESY-Equat%2E
 EXPNO 2
 PROCNO 1

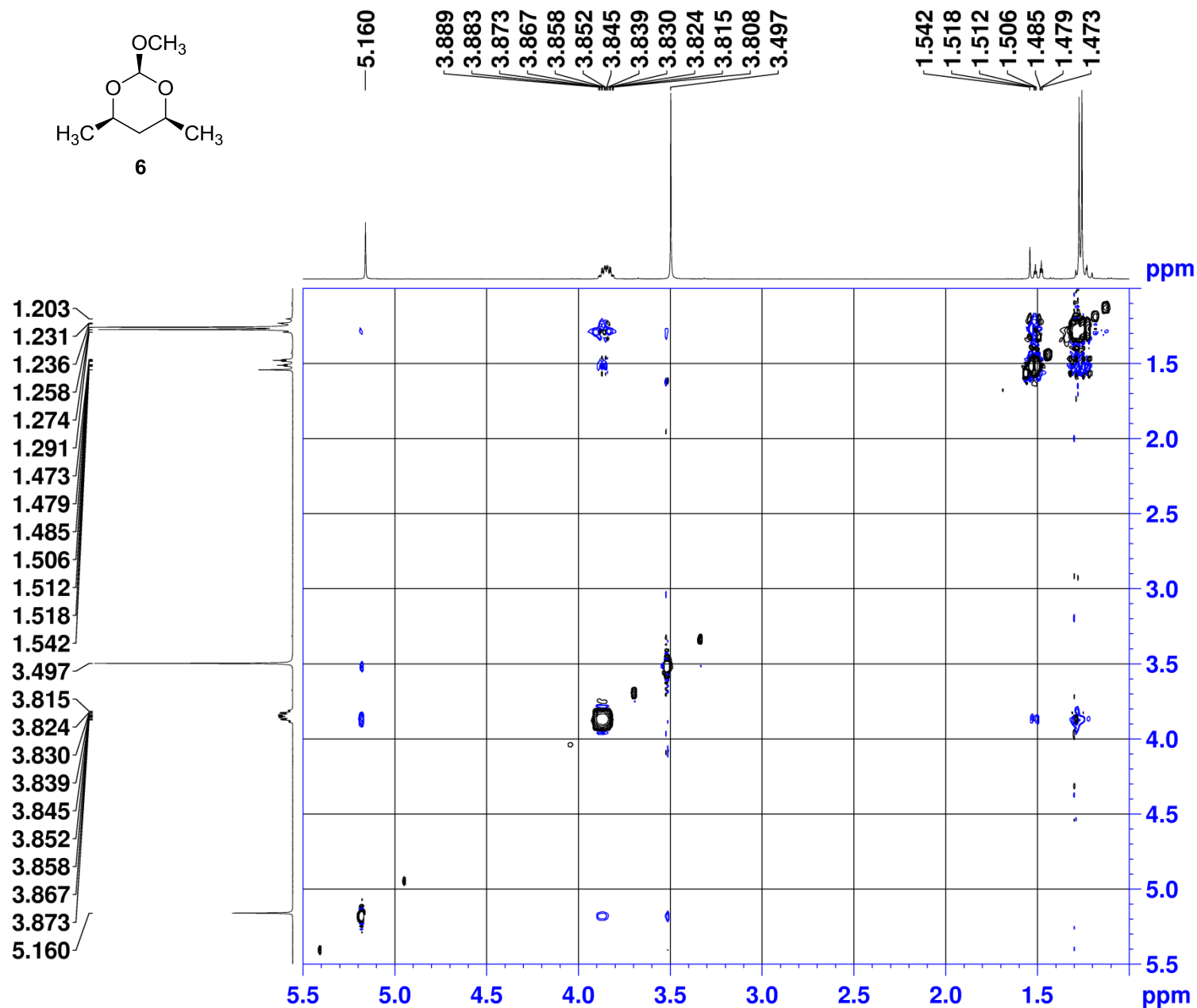
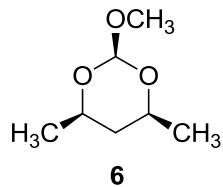
F2 - Acquisition Parameters
 Date_ 20161007
 Time 22.04 h
 INSTRUM spect
 PROBHD Z108618_0432 (
 PULPROG noesygpphph
 TD 2048
 SOLVENT CDC13
 NS 16
 DS 16
 SWH 4084.967 Hz
 FIDRES 3.989226 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 299.9 K
 D0 0.00010266 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec
 TDAV 1
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.50 usec
 P2 31.00 usec
 P17 2500.00 usec
 PLW1 11.99499989 W
 PLW10 4.26300001 W
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FnmODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0





Current Data Parameters
 NAME kl-1-203-HNOESY-Equat%2E
 EXPNO 2
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20161007
 Time 22.04 h
 INSTRUM spect
 PROBHD Z108618_0432 (
 PULPROG noesygpph
 TD 2048
 SOLVENT CDC13
 NS 16
 DS 4
 SWH 4084.967 Hz
 FIDRES 3.989226 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 299.9 K
 D0 0.00010266 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec
 TDAV 1
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.50 usec
 P2 31.00 usec
 P17 2500.00 usec
 PLW1 11.99499989 W
 PLW10 4.26300001 W
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FMODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0

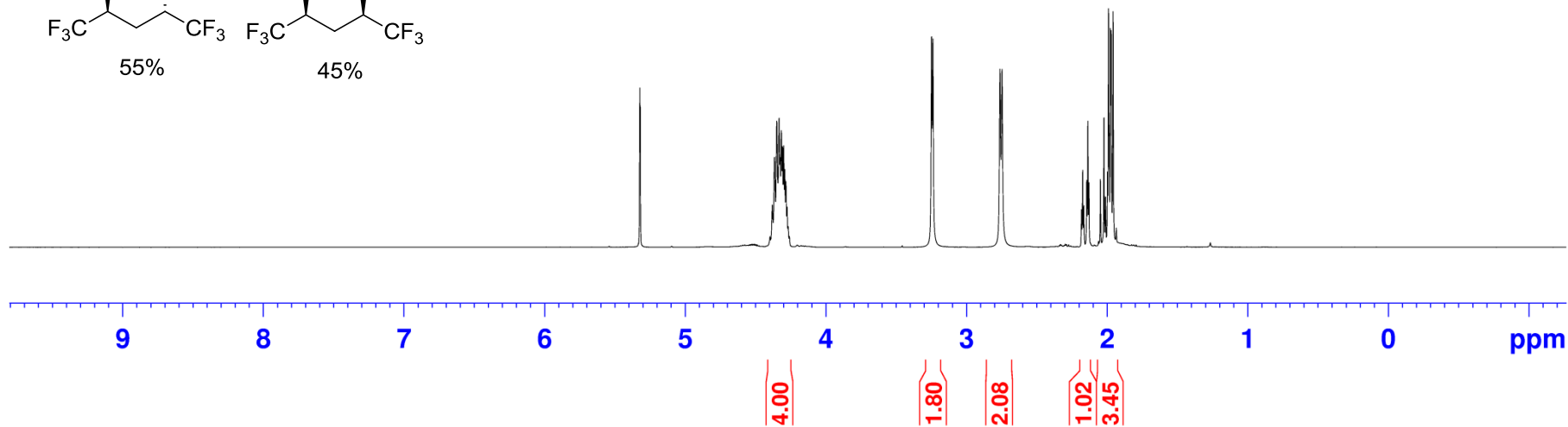
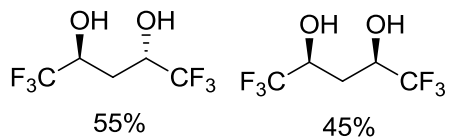
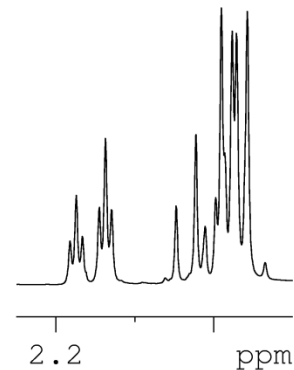
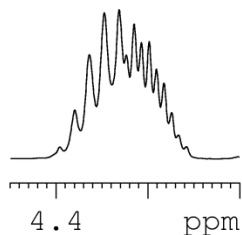


Current Data Parameters
NAME zs-2-27-H1
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20161010
Time 17.24 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zg30
TD 32768
SOLVENT CD2Cl2
NS 16
DS 2
SWH 7211.539 Hz
FIDRES 0.440157 Hz
AQ 2.2719147 sec
RG 114
DW 69.333 usec
DE 6.50 usec
TE 299.9 K
D1 0.50000000 sec
TD0 1
SFO1 400.1464009 MHz
NUC1 1H
P1 15.50 usec
PLW1 11.99499989 W

F2 - Processing parameters
SI 32768
SF 400.1440151 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

5.32
5.32
5.32
4.38
4.36
4.35
4.33
4.32
4.31
4.31
4.30
4.29
4.28
4.27
3.25
3.24
2.76
2.75
2.18
2.17
2.17
2.15
2.14
2.13
2.05
2.02
2.01
2.00
1.99
1.99
1.98
1.97
1.96





Current Data Parameters
 NAME: za-2-27-cl3
 EXPNO: 2
 PROCNO: 1

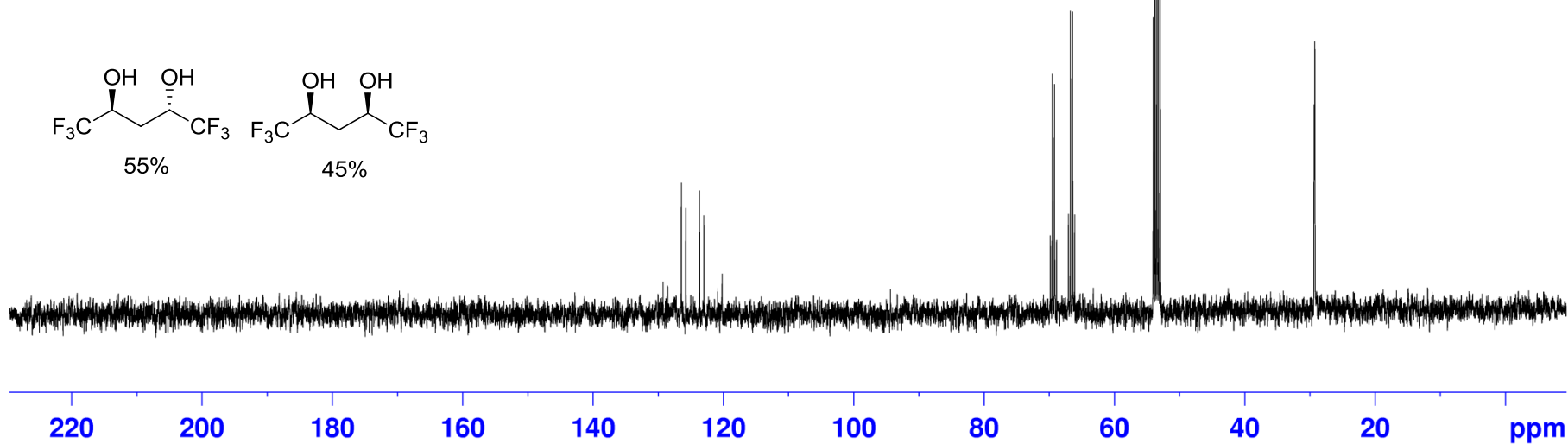
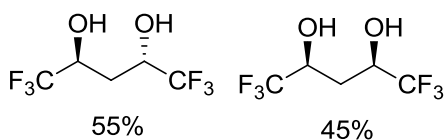
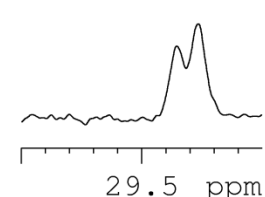
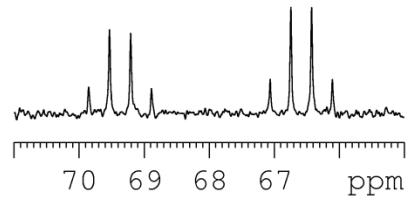
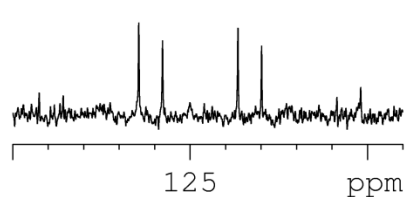
F2 - Acquisition Parameters
 Date_: 20161010
 Time: 17.36 h
 INSTRUM: spect
 PROBRD: z108618_0432 (4
 PULPROG: udeft
 TD: 17308
 SOLVENT: CD2Cl2
 NS: 96
 DS: 0
 SWH: 24038.461 Hz
 FIDRES: 2.7777728 Hz
 AQ: 0.3600064 sec
 RG: 203
 DW: 20.600 usec
 DE: 6.50 usec
 TE: 299.9 K
 D1: 4.00000000 sec
 D12: 0.00002000 sec
 D20: 200.00000000 sec
 TDO: 1
 SFO1: 100.6273568 MHz
 NUC1: 13C
 P1: 10.40 usec
 P13: 2000.00 usec
 P26: 50.00 usec
 P1W1: 50.00299835 W
 SPNAM[5]: Crp60comp.4
 SFOAL5: 0.500
 SPOFFS5: 0 Hz
 SPW5: 8.26329994 W
 SPNAM[9]: Crp60,0.5,20.1
 SFOAL6: 0.500
 SPOFFS6: 0 Hz
 SPW6: 8.26329994 W
 SFO2: 400.1456006 MHz
 NUC2: 1H
 CPDPRG[2]: waltz16
 PPD2: 90.00 usec
 P1W2: 11.99499989 W
 P1W12: 0.35578001 W

F2 - Processing parameters
 SI: 131072
 SF: 100.6162771 MHz
 WDW: EM
 SSB: 0
 LB: 2.00 Hz
 GB: 0
 PC: 1.40

129.24
 128.57
 126.45
 125.77
 123.65
 122.98
 120.85
 120.19

69.85
 69.53
 69.21
 68.89
 67.06
 66.74
 66.42
 66.11
 54.04
 53.77
 53.50
 53.23
 52.96

29.35
 29.26





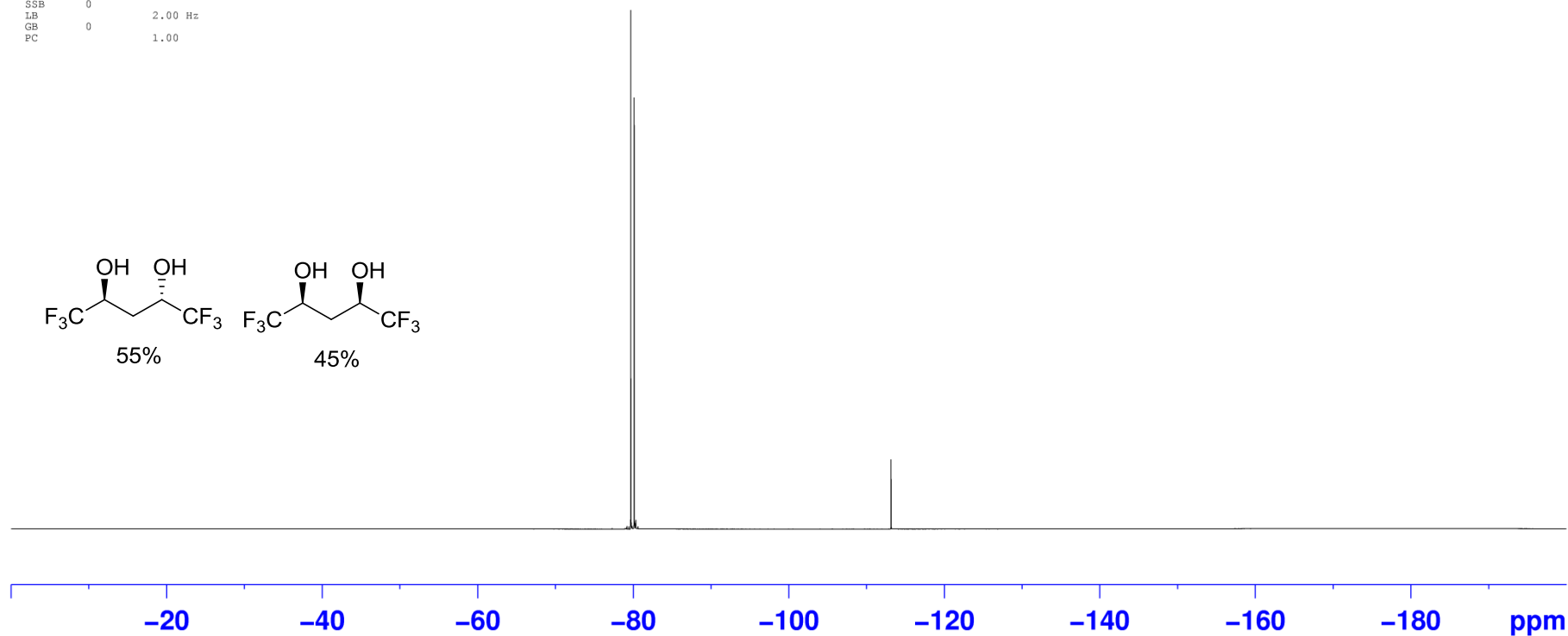
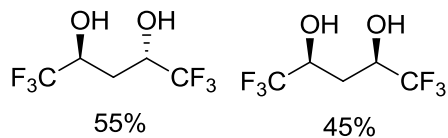
Current Data Parameters
NAME zs-2-27-F19
EXPNO 3
PROCNO 1

F2 - Acquisition Parameters
Date_ 20161010
Time 17.42 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zgfhgqn.2
TD 131072
SOLVENT CD2Cl2
NS 8
DS 4
SWH 89285.711 Hz
FIDRES 1.362392 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 299.9 K
D1 3.00000000 sec
D11 0.03000000 sec
D12 0.00002000 sec
TD0 1
SFO1 376.4738882 MHz
NUC1 19F
P1 11.05 usec
PLW1 17.98900032 W
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 11.99499989 W
PLW12 0.35578001 W

F2 - Processing parameters
SI 131072
SF 376.5112414 MHz
WDW EM
SSB 0
LB 2.00 Hz
GB 0
PC 1.00

-79.69
-80.12

-113.15

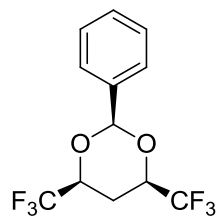




Current Data Parameters
NAME kl-3-6-pure-H1
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20161028
Time 20.50 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zg30
TD 32768
SOLVENT CDCl3
NS 16
DS 2
SWH 7211.539 Hz
FIDRES 0.440157 Hz
AQ 2.2719147 sec
RG 114
DW 69.333 usec
DE 6.50 usec
TE 300.0 K
D1 0.50000000 sec
TD0 1
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 32768
SF 400.1440094 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



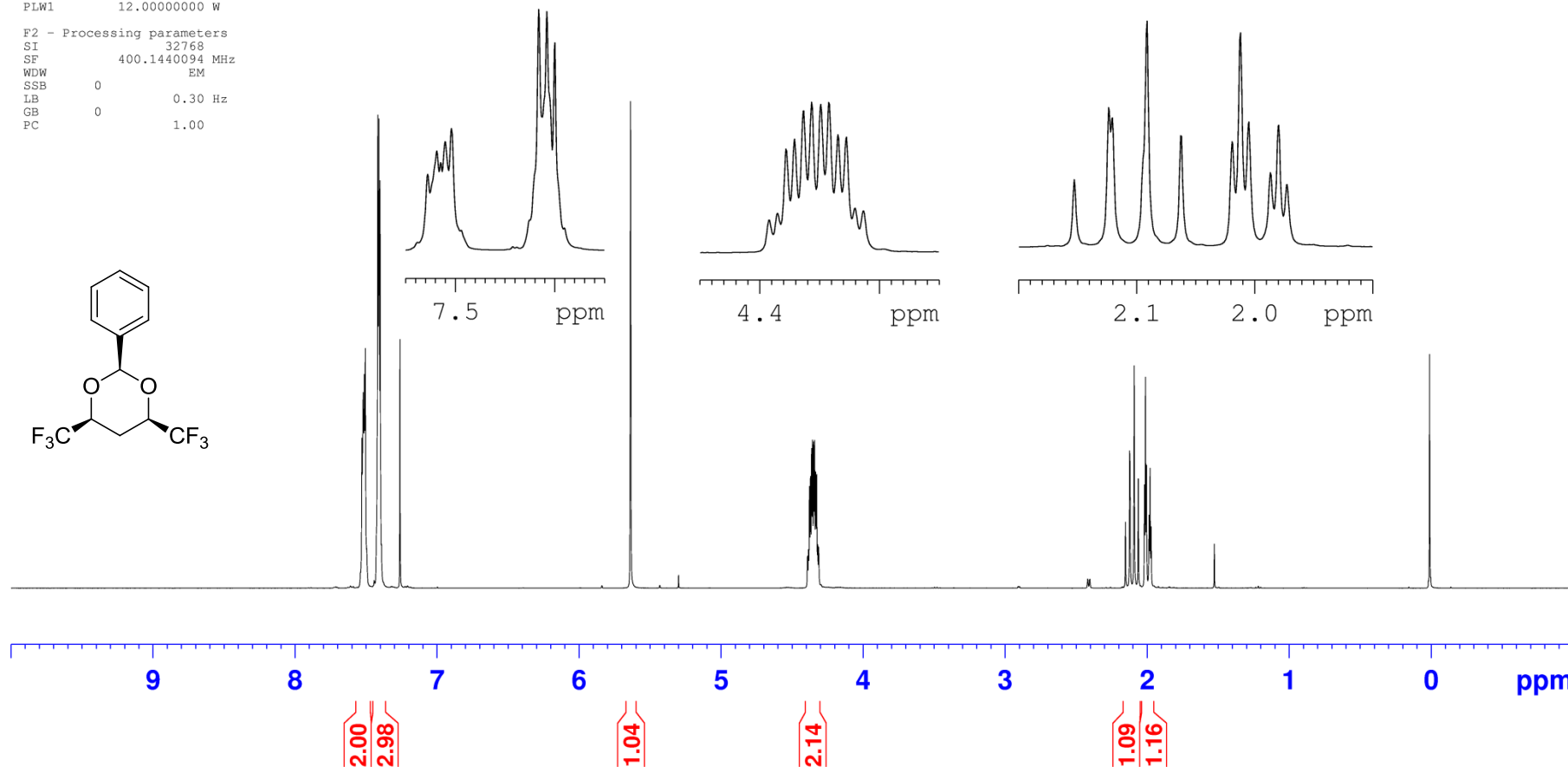
7.53
7.52
7.51
7.51
7.50
7.42
7.41
7.40
7.26

5.64

4.39
4.39
4.38
4.37
4.36
4.36
4.35
4.34
4.33
4.33
4.32
4.31

2.15
2.12
2.12
2.09
2.06
2.02
2.01
2.00
1.99
1.98
1.97
1.53

0.01

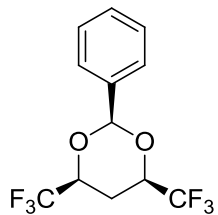




Current Data Parameters
NAME: k1-3-6-pure-cl3
EXPNO: 1
PROCNO: 1

F2 - Acquisition Parameters
Date_: 20161028
Time: 21:17 h
INSTRUM: spect
PROBHD: Z108618_0432 (
PULPROG: udeft
TD: 17308
SOLVENT: CDCl3
NS: 73
DS: 0
SWH: 24038.461 Hz
FIDRES: 2.777728 Hz
AQ: 0.3600064 sec
RG: 203
DW: 20.800 usec
DE: 6.50 usec
TE: 300.0 K
D1: 4.00000000 sec
D12: 0.00002000 sec
D20: 200.00000000 sec
TD0: 1
SFO1: 100.6273568 MHz
NUC1: 13C
P1: 10.40 usec
P13: 2000.00 usec
P26: 500.00 usec
P1M1: 50.00299855 W
SPNAM[5]: Crp60comp.4
SFOALS: 0.500
SPOFFS5: 0 Hz
SPW5: 8.26329994 W
SPNAM[8]: Crp60,0.5,20.1
SFOALS: 0.500
SPOFFS8: 0 Hz
SPW8: 8.26329994 W
SFO2: 400.1456006 MHz
NUC2: 1H
CPDPRG[2]: waltz16
PCPD2: 90.00 usec
PLM2: 11.99499989 W
PLM12: 0.35578001 W

F2 - Processing parameters
SI: 131072
SF: 100.6162674 MHz
WDW: EM
SSB: 0
LB: 2.00 Hz
GB: 0
PC: 1.40

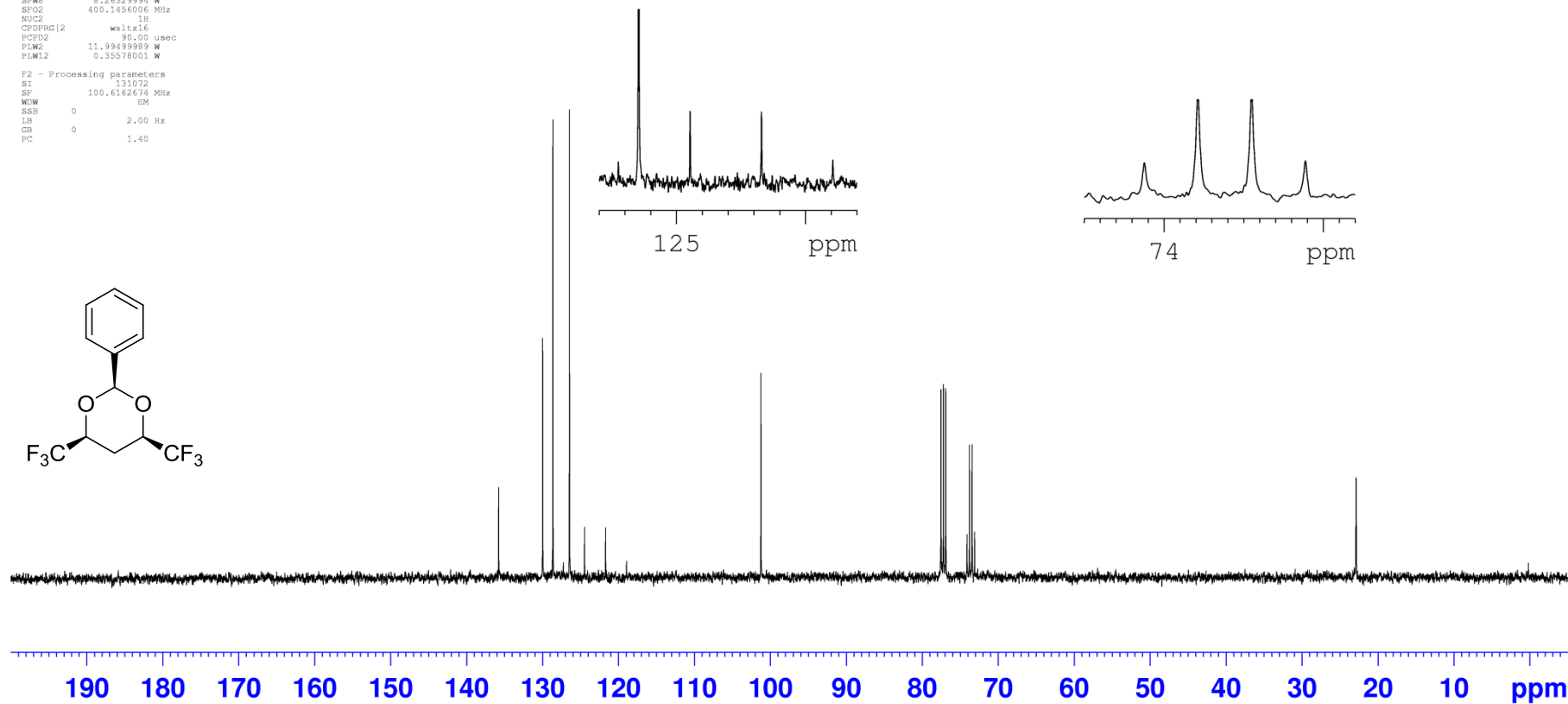


135.78
130.00
128.64
127.25
126.46
124.47
121.70
118.93

101.26

77.55
77.23
76.91
74.12
73.79
73.45
73.11

22.90

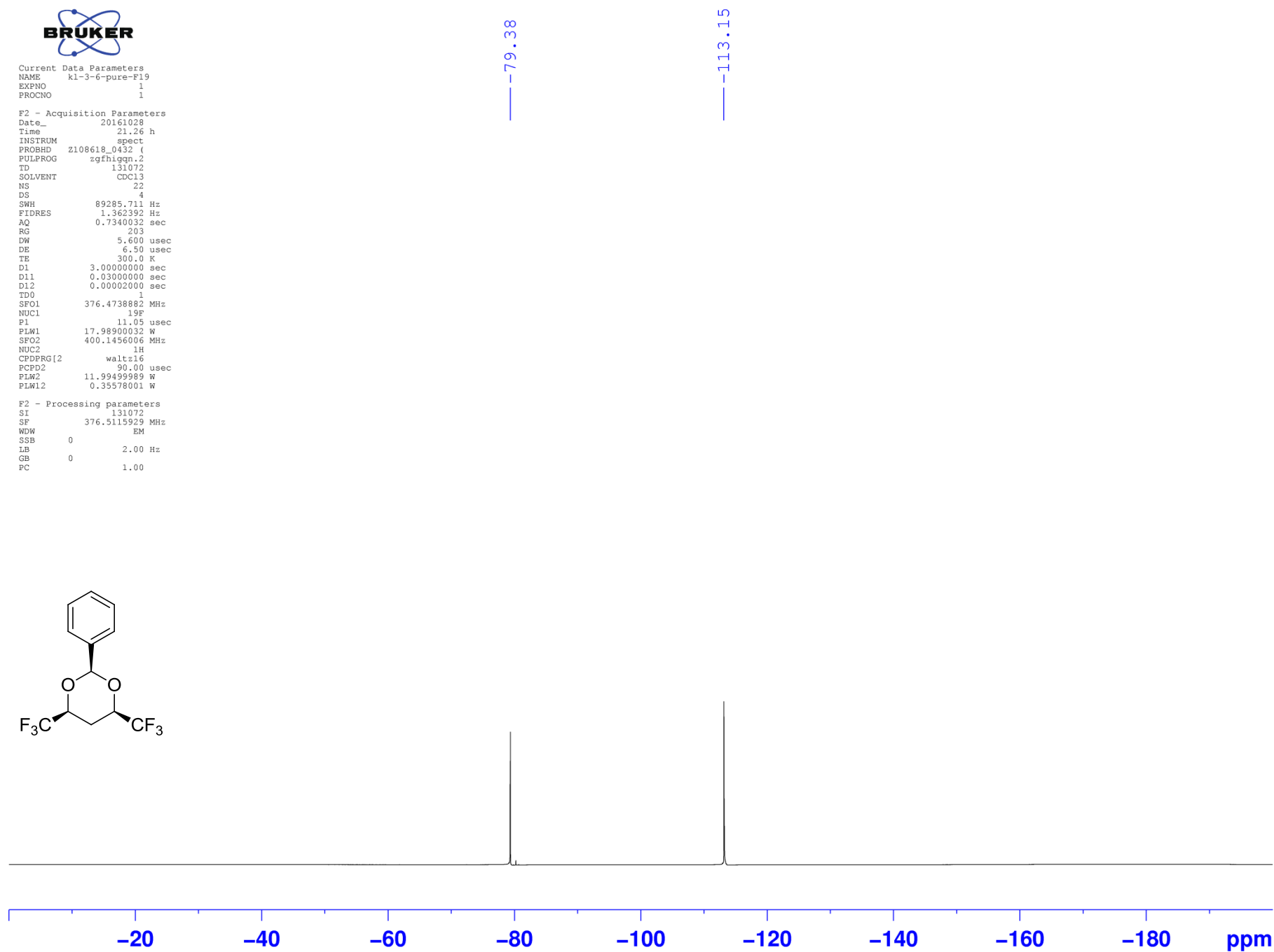
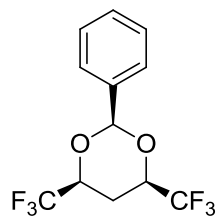




Current Data Parameters
NAME kl-3-6-pure-F19
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20161028
Time 21.26 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zgfhgqn.2
TD 131072
SOLVENT CDCl3
NS 22
DS 4
SWH 89285.711 Hz
FIDRES 1.362392 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 3.00000000 sec
D11 0.03000000 sec
D12 0.00002000 sec
TD0 1
SFO1 376.4738882 MHz
NUC1 19F
P1 11.05 usec
PLW1 17.98900032 W
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 11.99499989 W
PLW12 0.35578001 W

F2 - Processing parameters
SI 131072
SF 376.5115929 MHz
WDW EM
SSB 0
LB 2.00 Hz
GB 0
PC 1.00

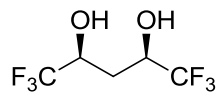




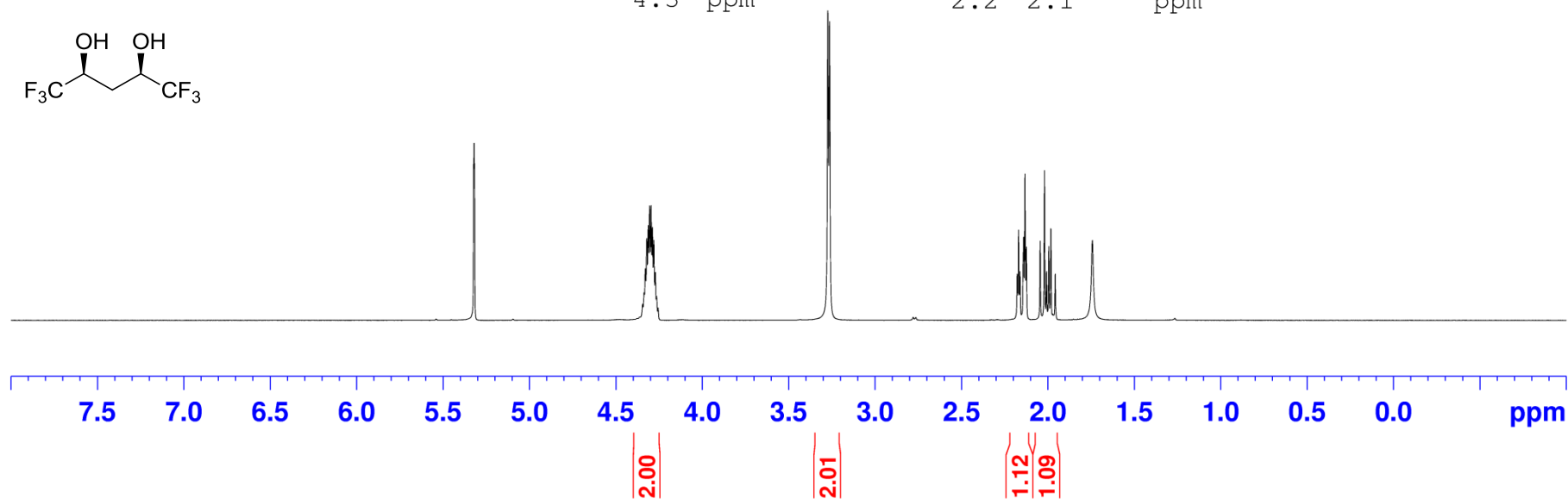
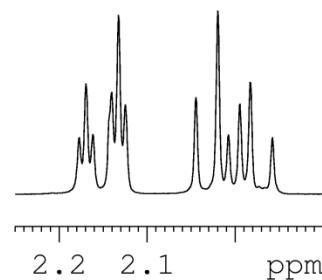
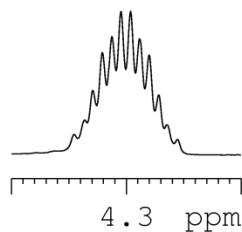
Current Data Parameters
NAME K1-1-pure meso CF3 diol-H1
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20161019
Time 16.40 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zg30
TD 32768
SOLVENT CD2Cl2
NS 16
DS 2
SWH 7211.539 Hz
FIDRES 0.440157 Hz
AQ 2.2719147 sec
RG 203
DW 69.333 usec
DE 6.50 usec
TE 299.9 K
D1 0.50000000 sec
TD0 1
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 32768
SF 400.1440155 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



5.32 5.32 5.32 4.35 4.34 4.33 4.32 4.31 4.30 4.30 4.29 4.28 4.27 4.26 3.27 3.26 2.18 2.17 2.16 2.14 2.13 2.12 2.04 2.02 2.01 1.99 1.98 1.96

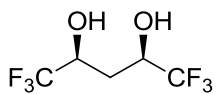




Current Data Parameters
NAME: kl-1-pure meso CF3 diol-C13
EXPNO: 1
PROCNO: 1

F2 - Acquisition Parameters
Date_: 20161019
Time: 17.17 h
INSTRUM: spect
PROBHD: Z108618_0432 (
PULPROG: udeft
TD: 17308
SOLVENT: CD2Cl2
NS: 217
DS: 0
SWH: 24038.461 Hz
FIDRES: 2.777728 Hz
AQ: 0.3600064 sec
RG: 203
DW: 20.800 usec
DE: 6.50 usec
TE: 299.9 K
D1: 4.00000000 sec
D12: 0.00002000 sec
D20: 200.00000000 sec
TD0: 1
SFO1: 100.6273568 MHz
NUC1: 13C
P1: 10.40 usec
P13: 2000.00 usec
P26: 500.00 usec
PLM1: 50.00299855 W
SPNAM[5]: Crp60comp.4
SFOALS: 0.500
SPOFFS5: 0 Hz
SPW5: 8.26329994 W
SPNAM[8]: Crp60,0.5,20.1
SFOALS: 0.500
SPOFFS8: 0 Hz
SPW8: 8.26329994 W
SFO2: 400.1456006 MHz
NUC2: 1H
CPDPRG[2]: waltz16
PCPD2: 90.00 usec
PLM2: 11.99499989 W
PLW12: 0.35578001 W

F2 - Processing parameters
SI: 331072
SF: 100.6162789 MHz
WDW: EM
SBB: 0
LB: 2.00 Hz
GB: 0
PC: 1.40

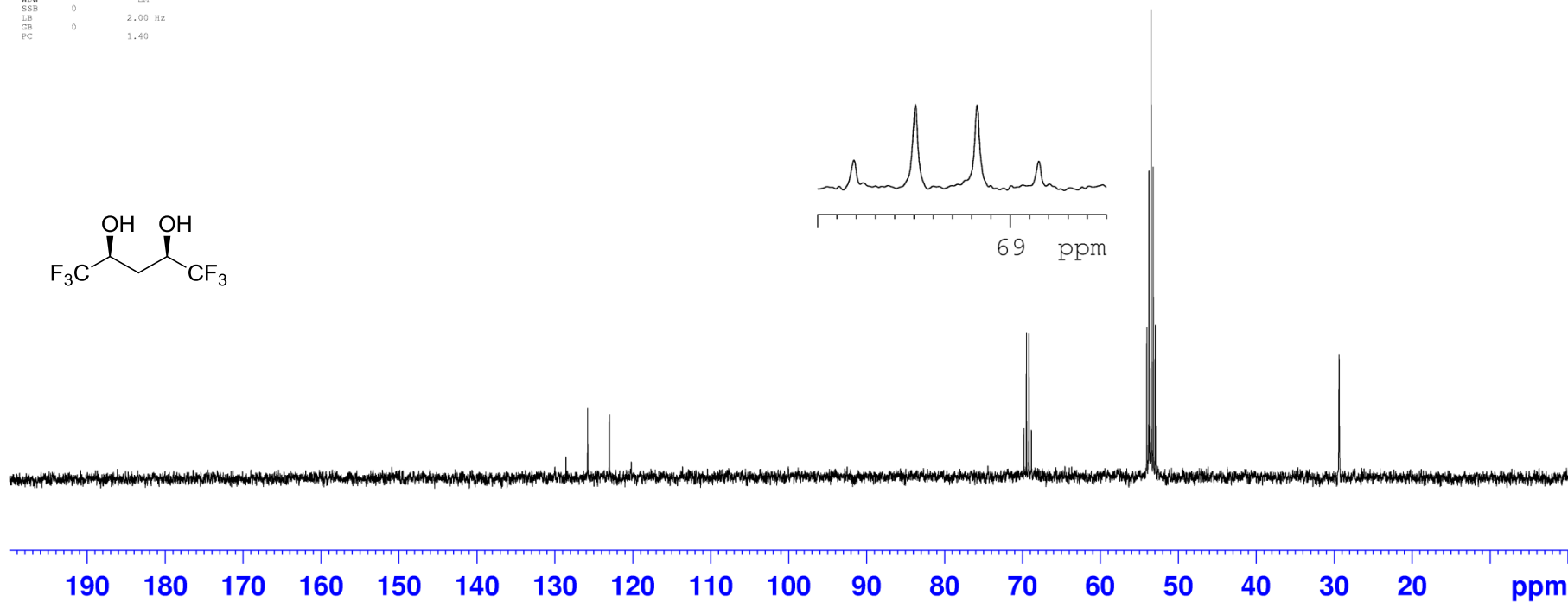


128.58
125.79
122.99
120.20

69.81
69.49
69.17
68.85

54.04
53.77
53.50
53.23
52.96

29.37





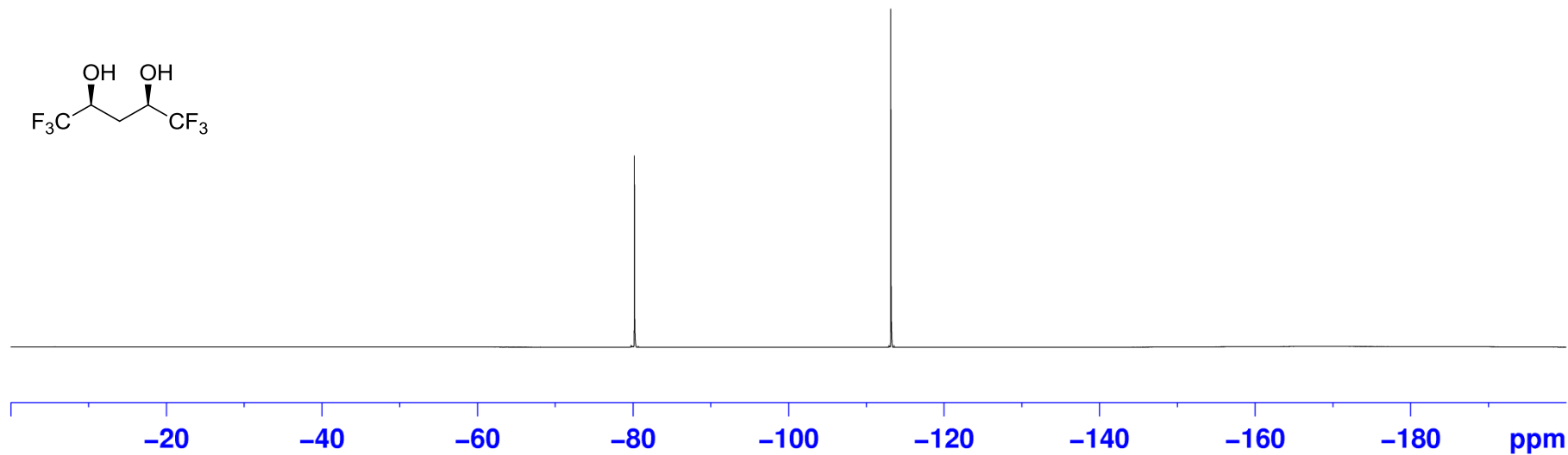
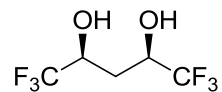
Current Data Parameters
NAME ki-1-pure meso CF3 diol-F19
EXPHO 3
PROCNO 1

F2 - Acquisition Parameters
Date_ 20161019
Time 17.22 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zgpg30
TD 131072
SOLVENT CD2Cl2
NS 16
DS 4
SWH 89285.711 Hz
FIDRES 1.362392 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 299.9 K
D1 3.00000000 sec
D11 0.03000000 sec
D12 0.00002000 sec
TD0 1
SFO1 376.4738882 MHz
NUC1 19F
P1 14.00 usec
PLW1 17.98900032 W
SFO2 400.1456006 MHz
NUC2 1H
CFDPRG[2] waltz16
PCPD2 90.00 usec
PLW2 11.99499989 W
PLW12 0.34439000 W

F2 - Processing parameters
SI 131072
SF 376.5112961 MHz
WDW EM
SSB 0
LB 2.00 Hz
GB 0
PC 1.00

— -80.18

— -113.15

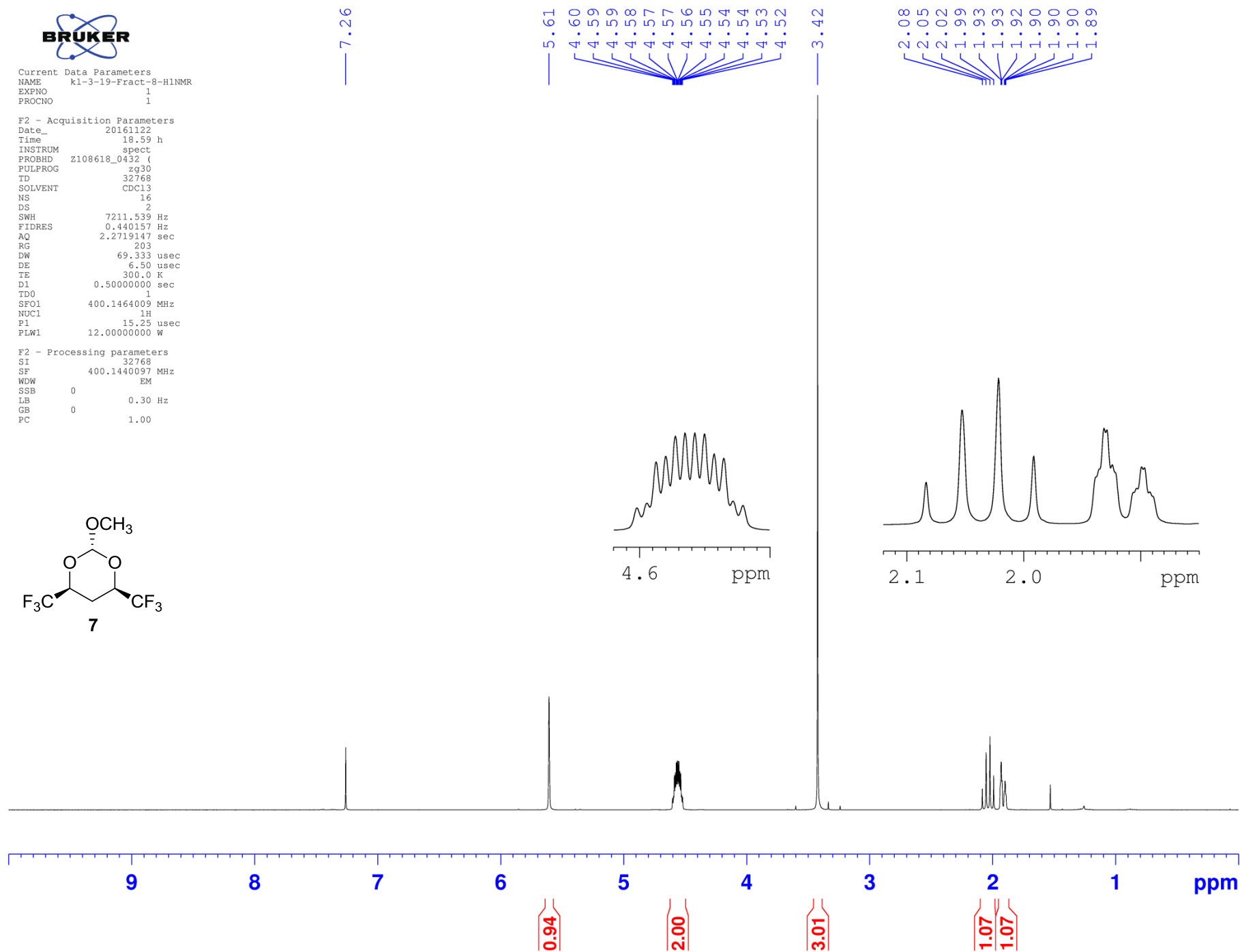
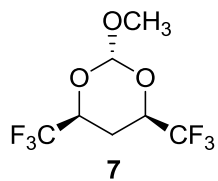




Current Data Parameters
NAME kl-3-19-Fract-8-H1NMR
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20161122
Time 18.59 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zg30
TD 32768
SOLVENT CDCl3
NS 16
DS 2
SWH 7211.539 Hz
FIDRES 0.440157 Hz
AQ 2.2719147 sec
RG 203
DW 69.333 usec
DE 6.50 usec
TE 300.0 K
D1 0.50000000 sec
TD0 1
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 32768
SF 400.1440097 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

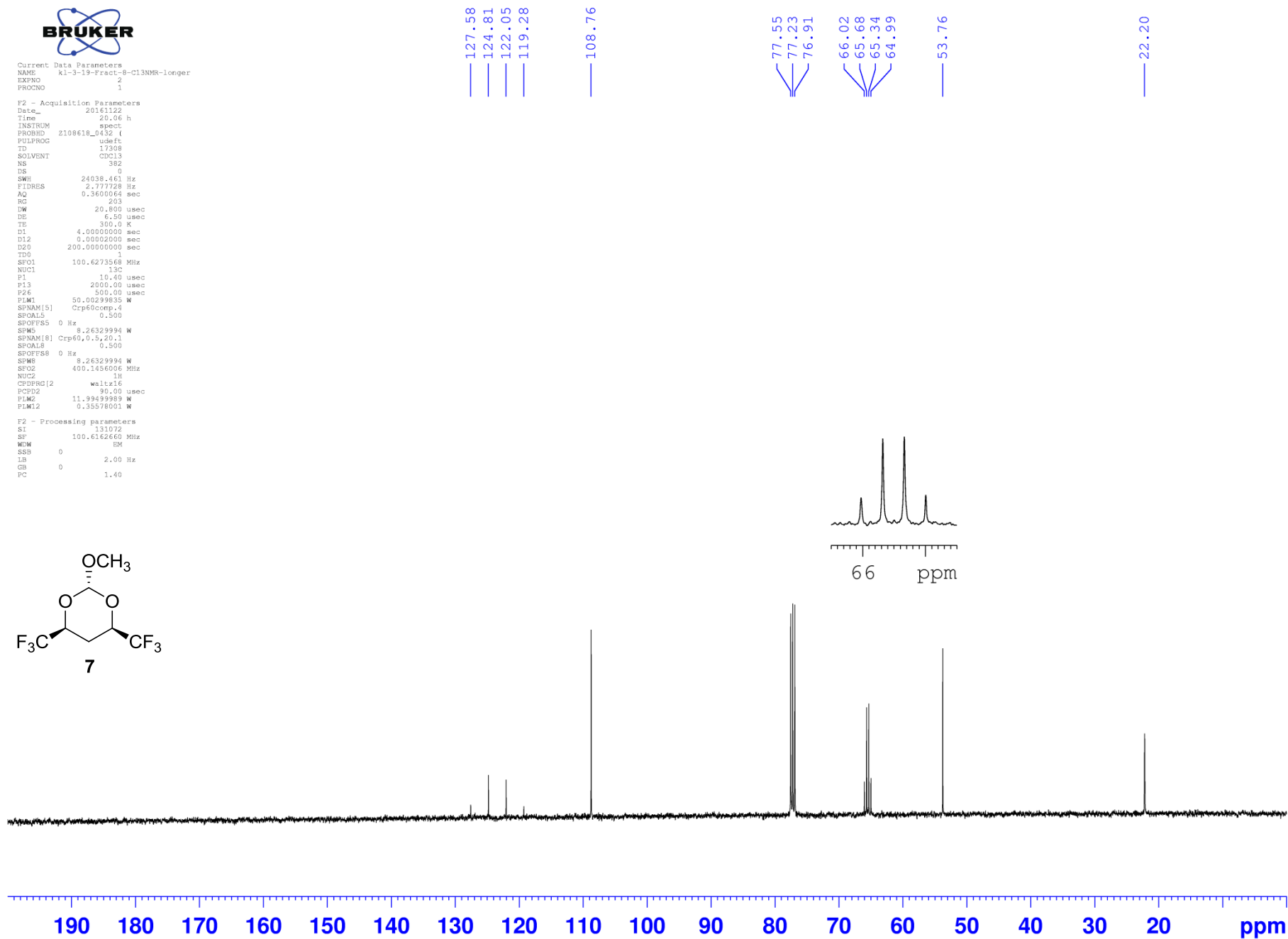
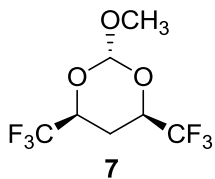




Current Data Parameters
NAME: k1-3-13-Fract-8-C13NMR-longer
EXPNO: 2
PROCNO: 1

F2 - Acquisition Parameters
Date_: 20161122
Time: 20.06 h
INSTRUM: spect
PROBHD: Z108618_0432 (4
PULPROG: udeft
TD: 17308
SOLVENT: CDCl3
NS: 382
DS: 0
SWH: 24038.461 Hz
FIDRES: 2.777728 Hz
AQ: 0.3600064 sec
RG: 203
DW: 20.600 usec
DE: 6.50 usec
TE: 300.0 K
D1: 4.00000000 sec
D12: 0.00002000 sec
D20: 200.00000000 sec
TD0: 1
SFO1: 100.6273568 MHz
NUC1: 13C
P1: 10.40 usec
P13: 2000.00 usec
P26: 500.00 usec
PLW1: 50.00299835 W
SPNAM[5]: Crp60comp.4
SFOAL5: 0 Hz
SPOFF55: 0 Hz
SPW5: 8.26329994 W
SPNAM[9]: Crp60,0.5,20.1
SFOAL6: 0 Hz
SPOFF58: 0 Hz
SPW6: 8.26329994 W
SFO2: 400.1456006 MHz
NUC2: 1H
CPDPRG[2]: waltz16
PCPD2: 90.00 usec
PLW2: 11.99499989 W
PLW12: 0.35578001 W

F2 - Processing parameters
SI: 131072
SF: 100.6162460 MHz
WDW: EM
SSB: 0
LB: 2.00 Hz
GB: 0
PC: 1.40

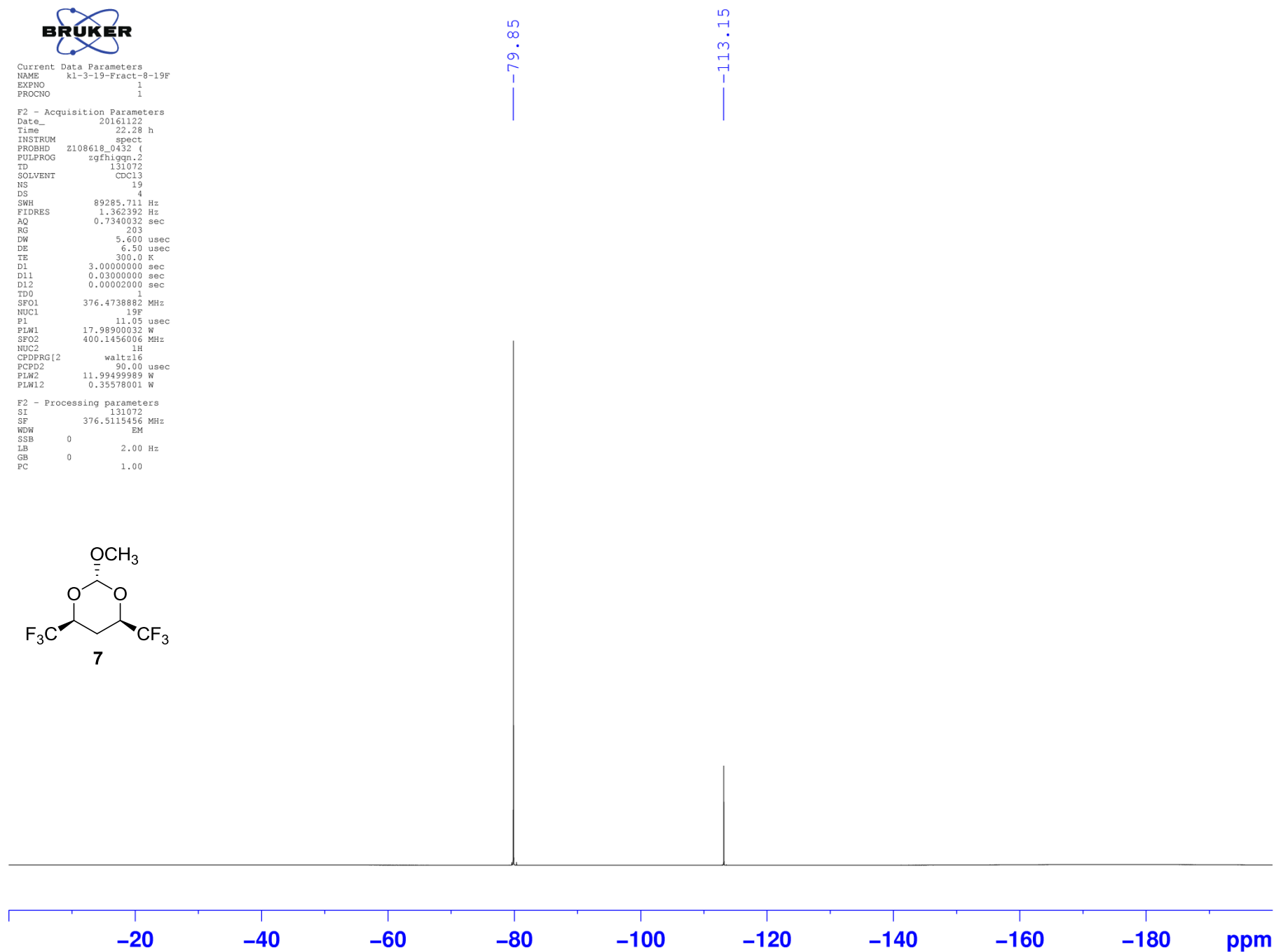
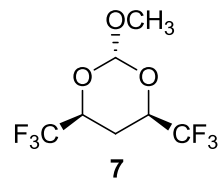




Current Data Parameters
NAME k1-3-19-Fract-8-19F
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20161122
Time 22.28 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zgfhgqn.2
TD 131072
SOLVENT CDCl3
NS 19
DS 4
SWH 89285.711 Hz
FIDRES 1.362392 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 3.00000000 sec
D11 0.03000000 sec
D12 0.00002000 sec
TD0 1
SFO1 376.4738882 MHz
NUC1 19F
P1 11.05 usec
PLW1 17.98900032 W
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 11.99499989 W
PLW12 0.35578001 W

F2 - Processing parameters
SI 131072
SF 376.5115456 MHz
WDW EM
SSB 0
LB 2.00 Hz
GB 0
PC 1.00





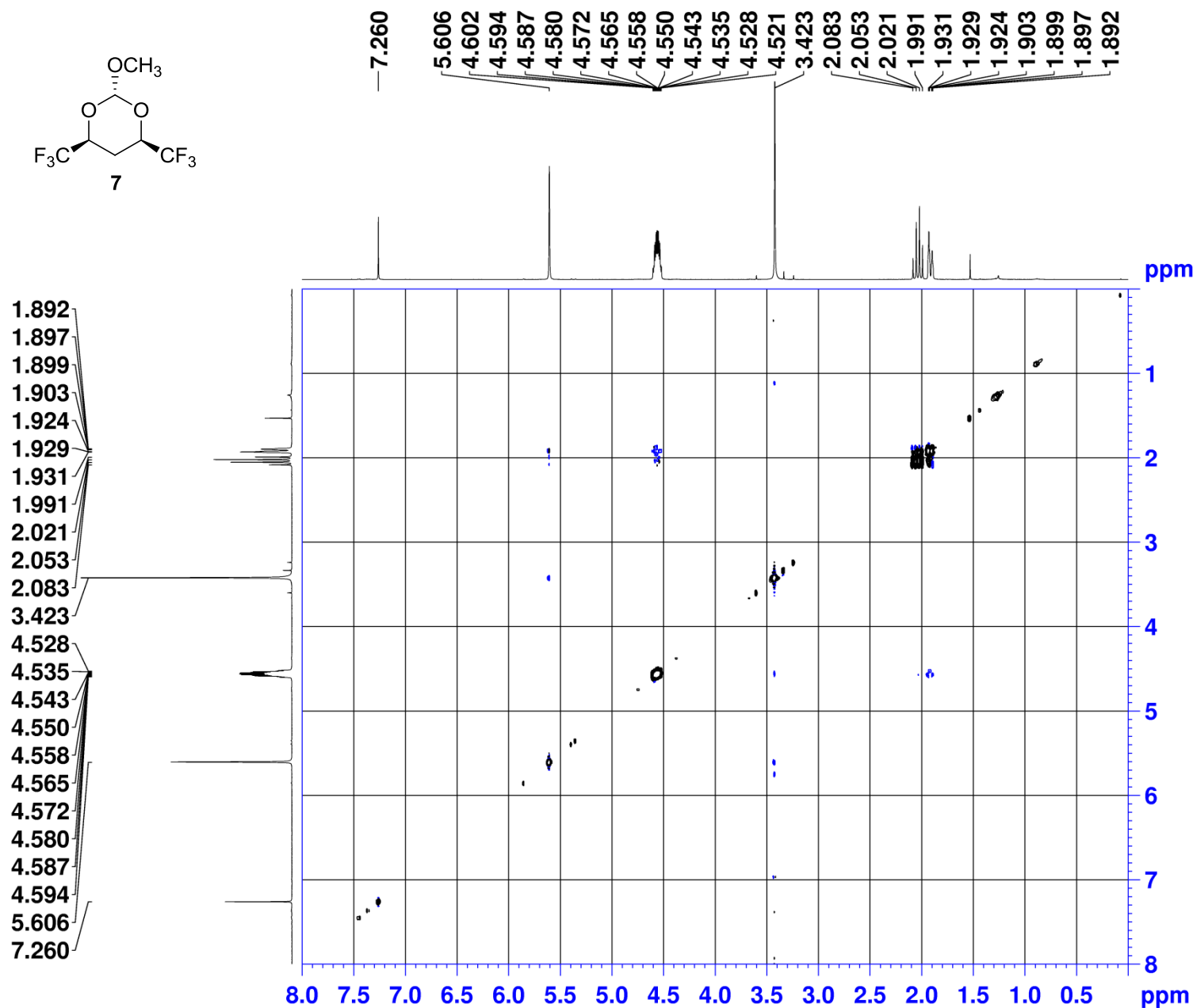
Current Data Parameters
 NAME k1-3-19-Fract-8-HNOESY
 EXPNO 1
 PROCNO 1

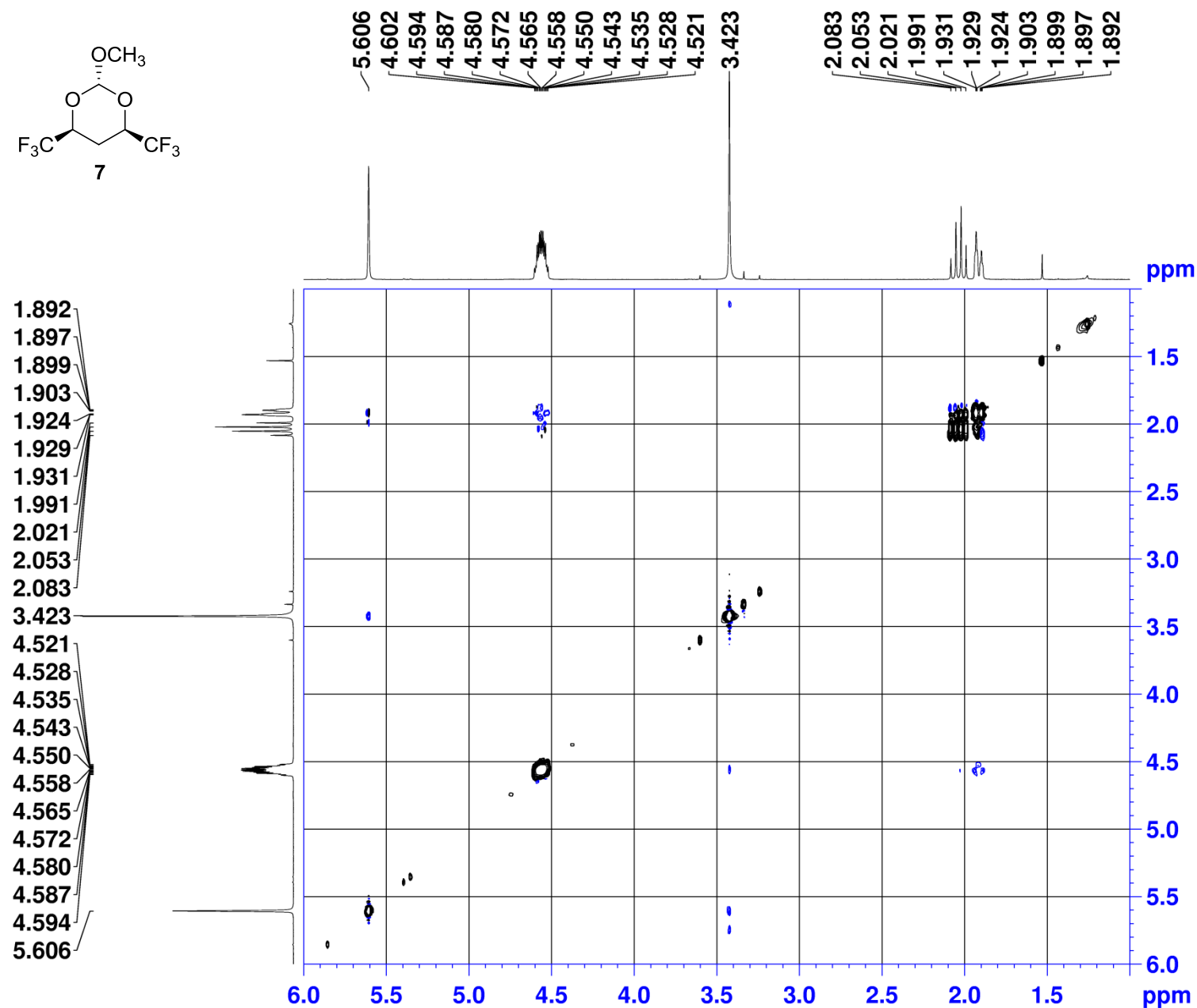
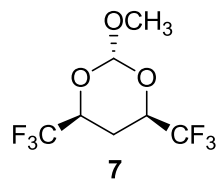
F2 - Acquisition Parameters
 Date_ 20161122
 Time 20.25 h
 INSTRUM spect
 PROBHD Z108618_0432 (
 PULPROG noesygpph
 TD 2048
 SOLVENT CDC13
 NS 4
 DS 16
 SWH 4084.967 Hz
 FIDRES 3.989226 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 D0 0.00010266 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 INO 0.00024480 sec
 TDAV 1
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.50 usec
 P2 31.00 usec
 P17 2500.00 usec
 PLW1 11.99499989 W
 PLW10 4.26300001 W
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FMODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440082 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440083 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0





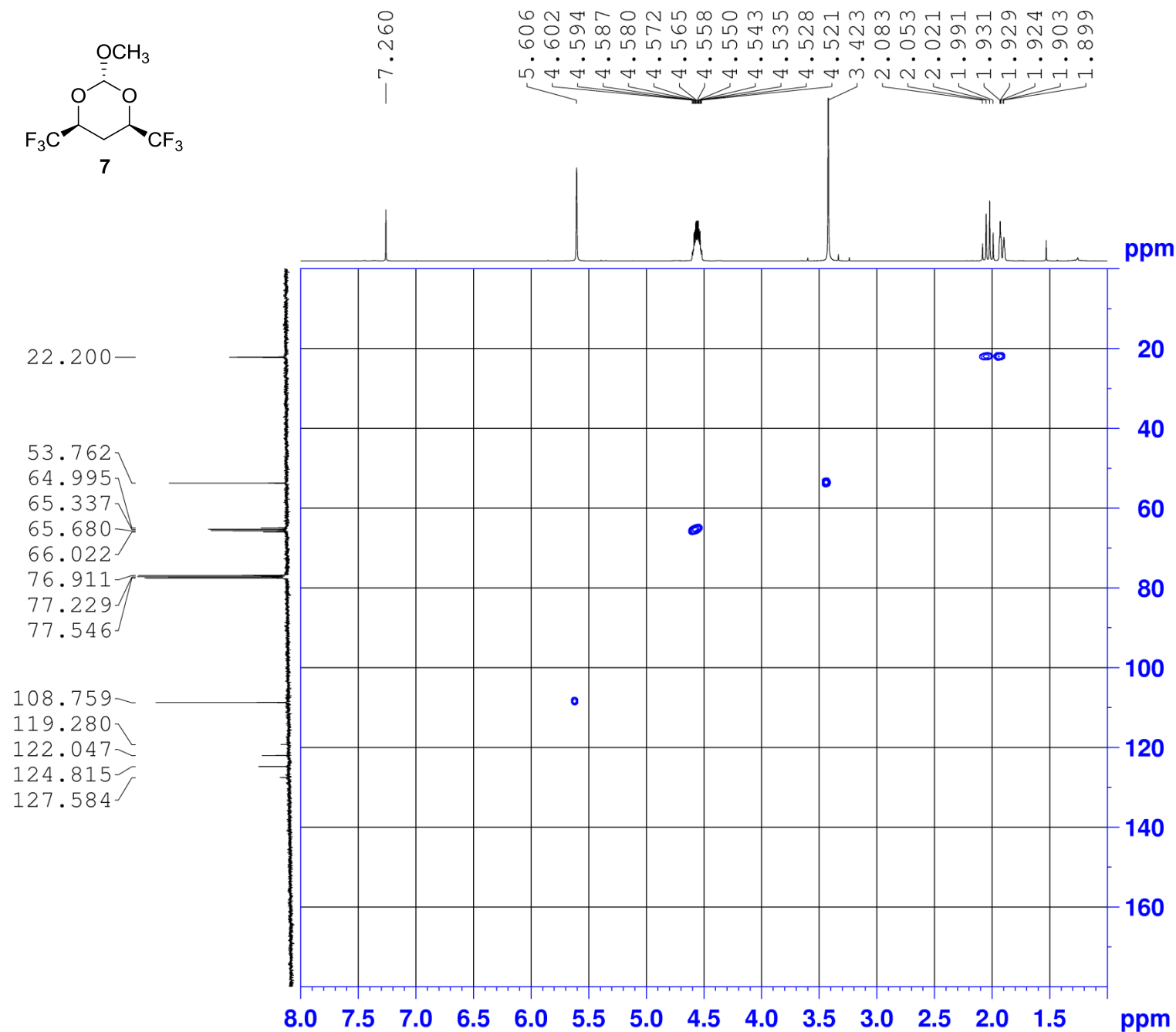
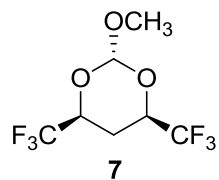
Current Data Parameters
 NAME k1-3-19-Fract-8-HNOESY
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20161122
 Time 20.25 h
 INSTRUM spect
 PROBHD Z108618_0432 (
 PULPROG noesygpph
 TD 2048
 SOLVENT CDC13
 NS 4
 DS 16
 SWH 4084.967 Hz
 FIDRES 3.989226 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 D0 0.00010266 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec
 T1 1
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.50 usec
 P2 31.00 usec
 P17 2500.00 usec
 PLW1 11.99499989 W
 PLW10 4.26300001 W
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 F1MODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440082 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440083 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0



Current Data Parameters
 NAME kl-3-19-Fract-8-HSQC
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20161122
 Time 20.08 h
 INSTRUM spect
 PROBHD Z108618_0432 4
 PULPROG hsqcetgpa1sp2.3
 TD 1024
 SOLVENT CDCl3
 NS 4
 DS 16

SWH 6410.256 Hz
 FIDRES 12.520032 Hz
 AQ 0.0798720 sec
 RG 203
 DW 78.000 usec
 DE 6.50 usec
 TE 300.0 K
 CNST2 145.000000
 CNST17 -0.5000000
 D0 0.00000300 sec
 D1 1.50000000 sec
 D4 0.00172414 sec
 D11 0.03000000 sec
 D16 0.00020000 sec
 D21 0.003606000 sec
 D24 0.00089000 sec
 IN0 0.0003010 sec
 Tdav 1
 SFO1 400.1458807 MHz
 NUC1 1H
 P1 15.50 usec
 P2 31.00 usec
 P28 1000.00 usec
 PLW1 11.99499989 W
 SFO2 100.6233320 MHz
 NUC2 13C
 CPDPRG2 2 bl_psm4sp_4sp.2
 P3 10.40 usec
 P14 500.00 usec
 P24 2000.00 usec
 P31 1900.00 usec
 P63 1500.00 usec

PLW0 0 W
 PLW2 50.00299835 W
 PLW2 0.84504998 W
 SPNAM[3] Crp60,0.5,20.1
 SPOAL3 0.500
 SPOFFS3 0 Hz
 SPW3 8.26329994 W
 SPNAM[7] Crp60comp.4
 SPOAL7 0.500
 SPOFFS7 0 Hz
 SPW7 8.26329994 W
 SPNAM[14] Crp32,1.5,20.2
 SPOAL14 0.500
 SPOFFS14 0 Hz
 SPW14 3.52570009 W
 SPNAM[18] Crp60_xfillt.2
 SPOAL18 0.500
 SPOFFS18 0 Hz
 SPW18 1.98000002 W
 SPNAM[31] Crp32,1.5,20.2
 SPOAL31 0.500
 SPOFFS31 0 Hz
 SPW31 0.88142002 W
 GPNAM[1] SMSQ10.100
 GPZ1 80.00 %
 GPNAM[2] SMSQ10.100
 GPZ2 20.10 %
 GPNAM[3] SMSQ10.100
 GPZ3 11.00 %
 GPNAM[4] SMSQ10.100
 GPZ4 -5.00 %
 P16 1000.00 usec
 P19 600.00 usec

F1 - Acquisition parameters
 TD 128
 SFO1 100.6233 MHz
 FIDRES 129.775742 Hz
 SW 165.084 ppm
 F2MODE Echo-Antiecho

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.40

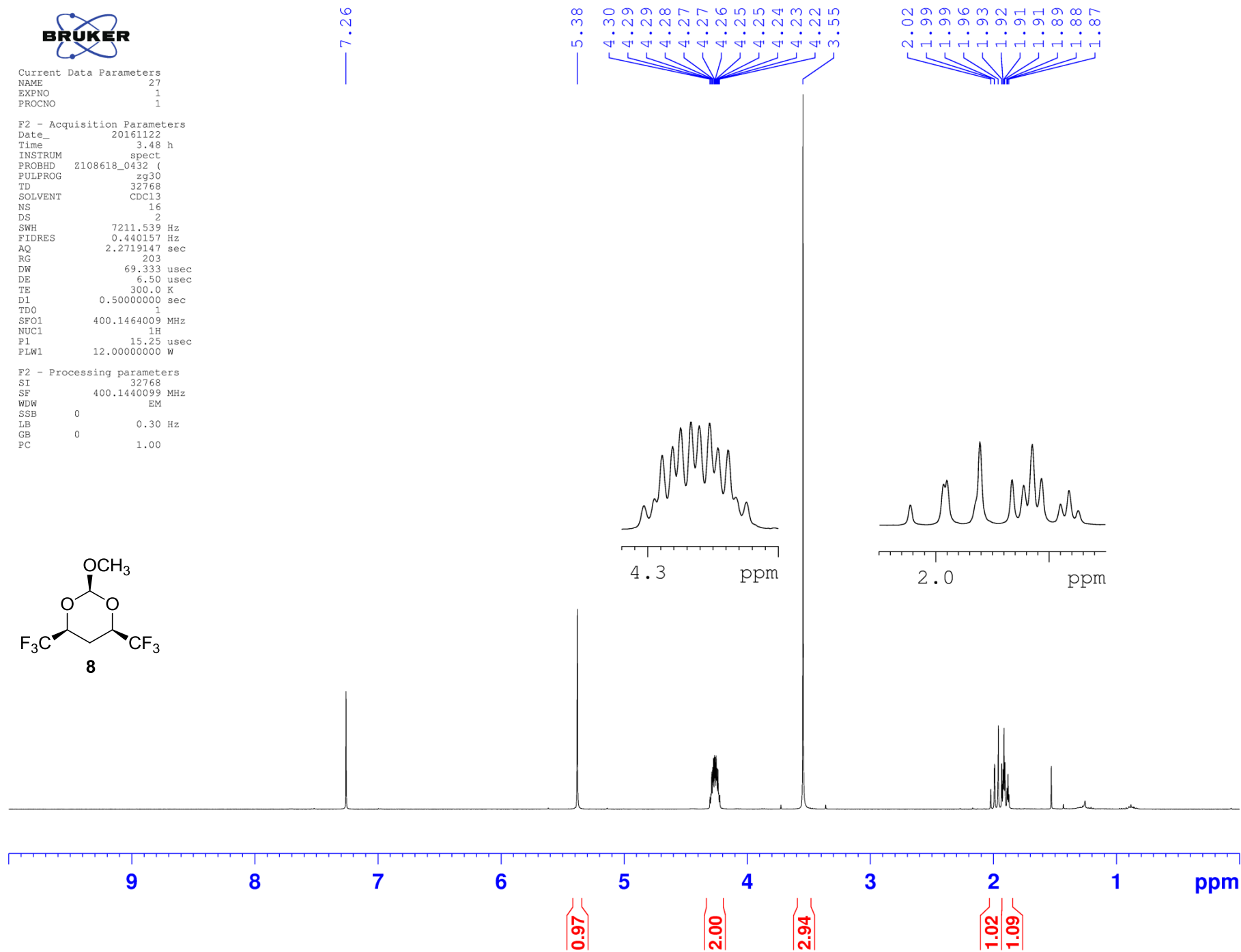
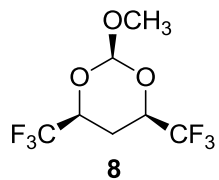
F1 - Processing parameters
 SI 1024
 MC2 echo-antiecho
 SF 100.6162890 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0



Current Data Parameters
NAME 27
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20161122
Time 3.48 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zg30
TD 32768
SOLVENT CDC13
NS 16
DS 2
SWH 7211.539 Hz
FIDRES 0.440157 Hz
AQ 2.2719147 sec
RG 203
DW 69.333 usec
DE 6.50 usec
TE 300.0 K
D1 0.50000000 sec
TD0 1
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 32768
SF 400.1440099 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

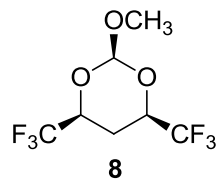




Current Data Parameters
NAME 27-cl3
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20161122
Time 4.30 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG udeft
TD 17308
SOLVENT CDCl3
NS 449
DS 0
SWH 24038.461 Hz
FIDRES 2.777728 Hz
AQ 0.3600064 sec
RG 203
DW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 4.00000000 sec
D12 0.00002000 sec
D20 200.00000000 sec
TD0 1
SFO1 100.6273568 MHz
NUC1 13C
P1 10.40 usec
P13 2000.00 usec
P26 500.00 usec
P1M1 50.00299855 W
SPNAM[5] Crp60comp.4
SFOALS 0.500
SFOFSS 0 Hz
SPW5 8.26329994 W
SPNAM[8] Crp60,0.5,20.1
SFOALS 0.500
SFOFSS 0 Hz
SPW8 8.26329994 W
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG[2] waltz16
PCPD2 90.00 usec
PLM2 11.99499989 W
PLM12 0.35578001 W

F2 - Processing parameters
SI 131072
SF 100.6162667 MHz
WDW EM
SBB 0
LB 2.00 Hz
GB 0
PC 1.40

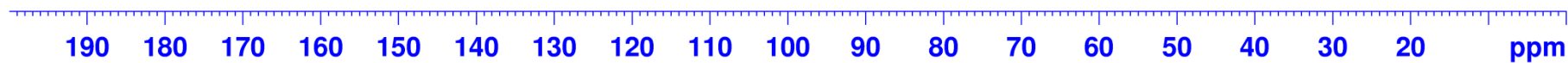
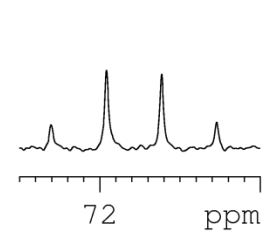


126.97
124.20
121.43
118.65
110.60

77.55
77.23
76.91
72.30
71.96
71.61
71.27

52.50

22.06

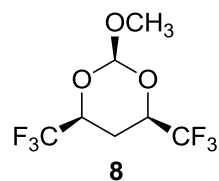




Current Data Parameters
NAME kl-3-19-fract26-27-F19-1
EXPNO 1
PROCNO 1

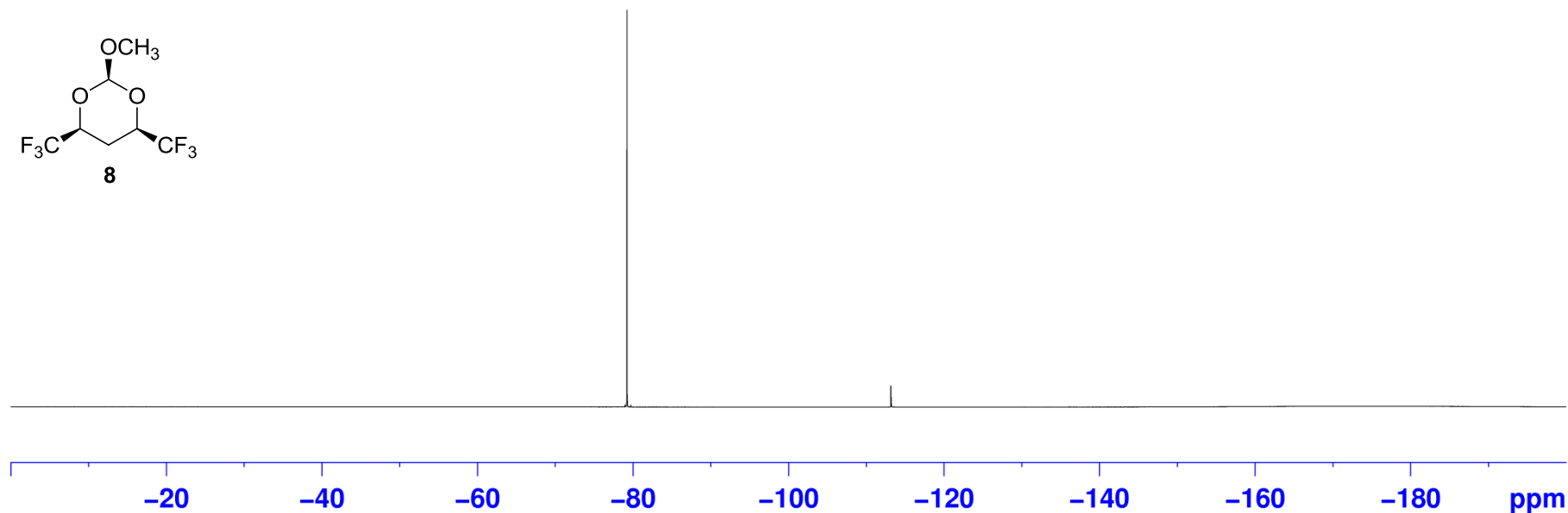
F2 - Acquisition Parameters
Date_ 20161122
Time 6.06 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zgfhgqn.2
TD 131072
SOLVENT CDCl3
NS 8
DS 4
SWH 89285.711 Hz
FIDRES 1.362392 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 3.00000000 sec
D11 0.03000000 sec
D12 0.00002000 sec
TD0 1
SFO1 376.4738882 MHz
NUC1 19F
P1 14.00 usec
PLW1 17.98900032 W
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 11.99499989 W
PLW12 0.34439000 W

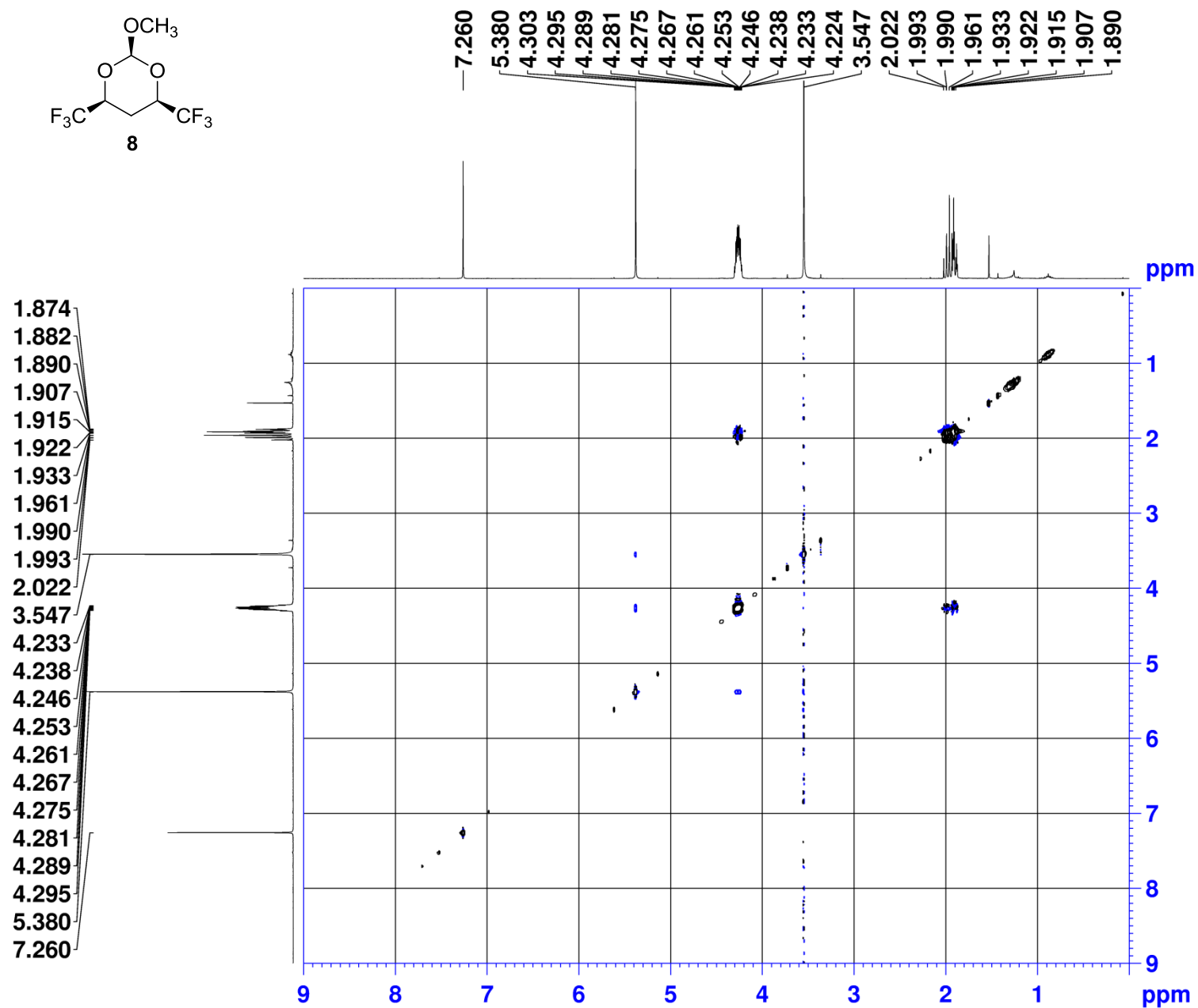
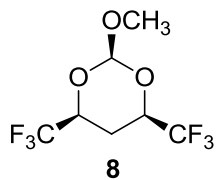
F2 - Processing parameters
SI 131072
SF 376.5115549 MHz
WDW EM
SSB 0
LB 2.00 Hz
GB 0
PC 1.00



— -79.23

— -113.15





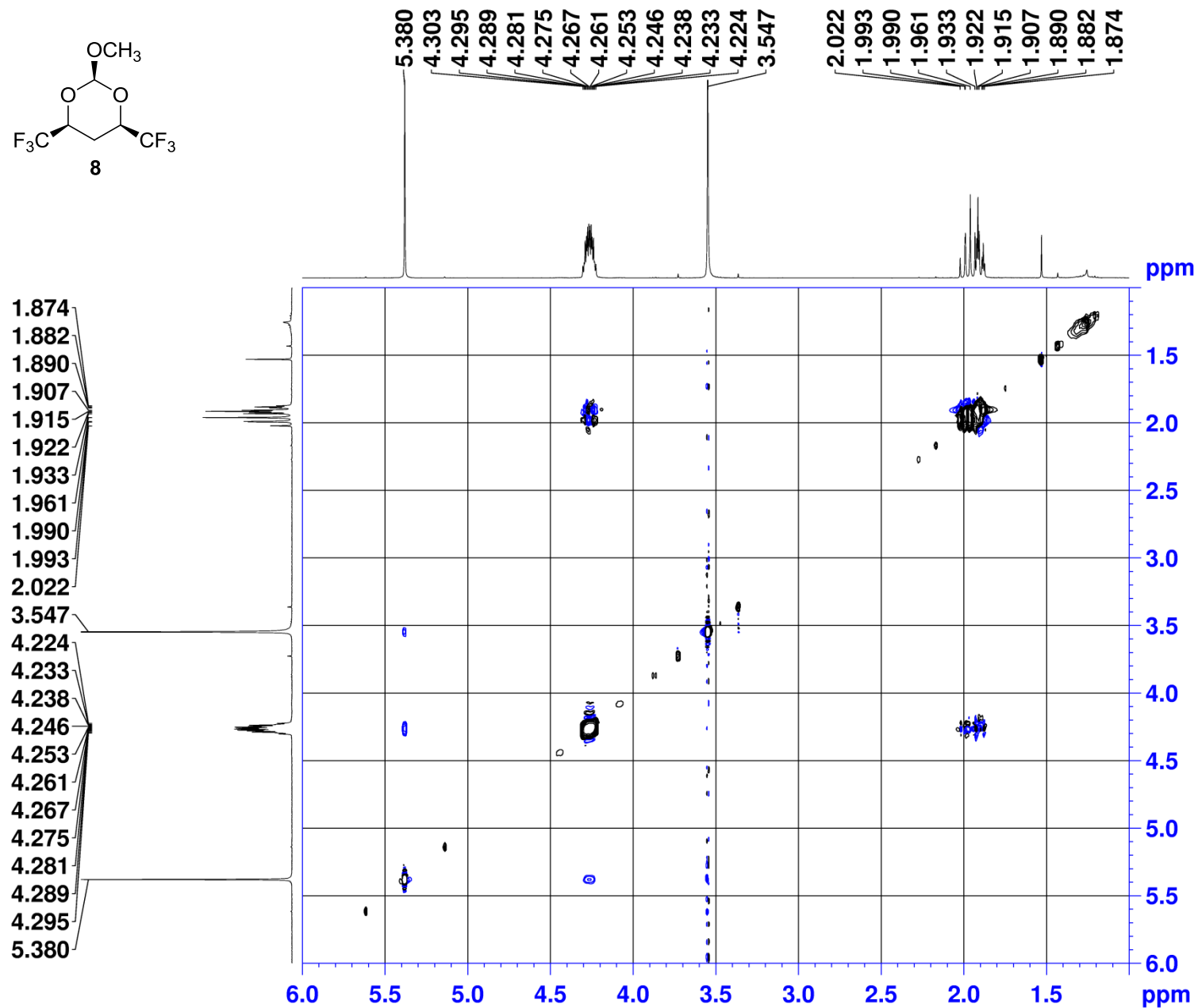
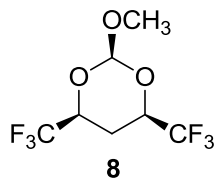
Current Data Parameters
NAME kl-3-19-fract26-27-HNOSY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20161122
Time 5.03 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG noesygpphpp
TD 2048
SOLVENT CDCl3
NS 4
DS 16
SWH 4084.967 Hz
FIDRES 3.989226 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
DO 0.00010266 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec
TDav 1
SFO1 400.1458419 MHz
NUC1 1H
P1 15.50 usec
P2 31.00 usec
P17 2500.00 usec
PLW1 11.99499989 W
PLW10 4.26300001 W
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440082 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440082 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0



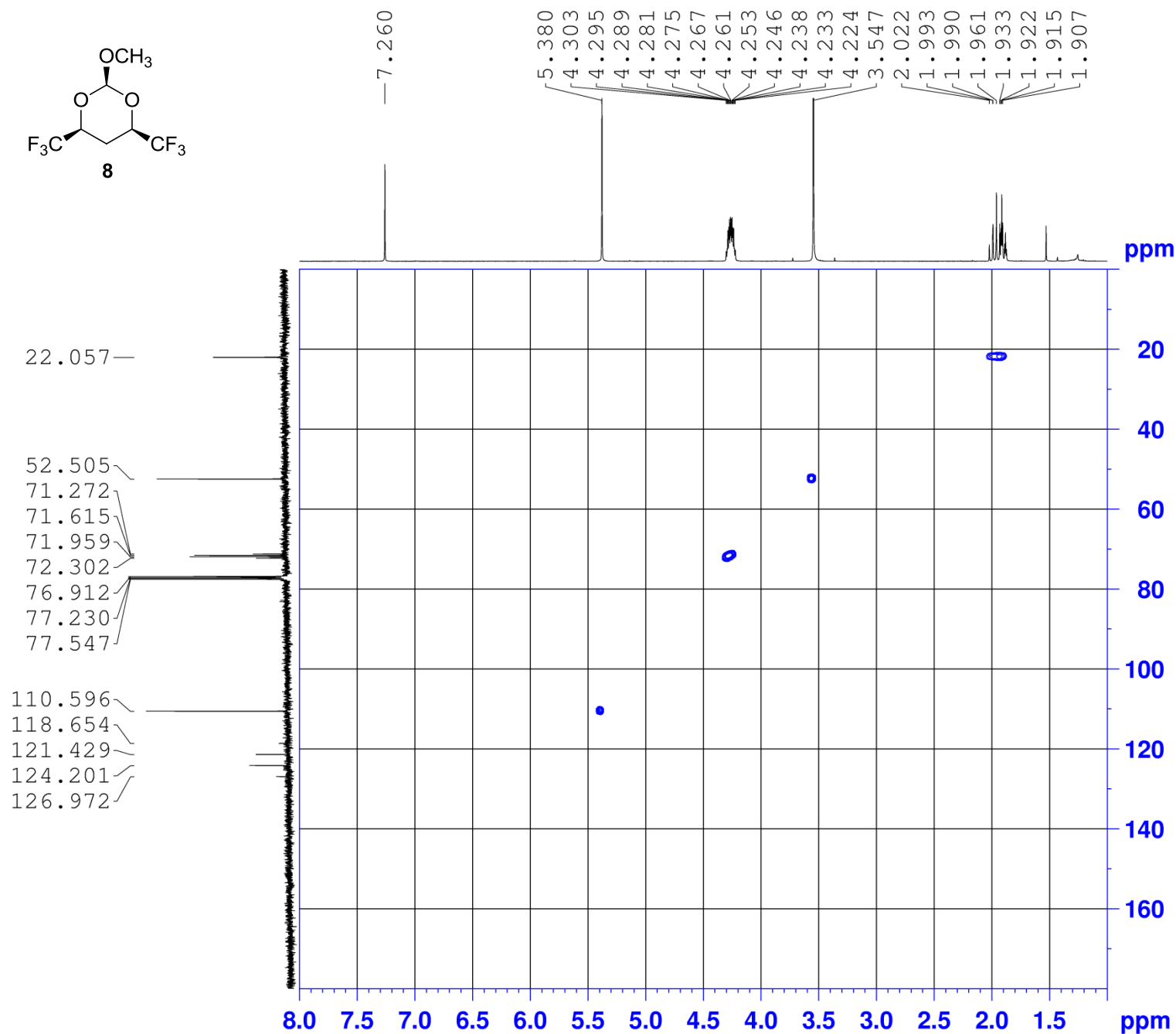
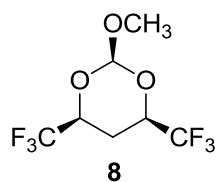
Current Data Parameters
 NAME k1-3-19-fract26-27-HNOESY
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20161122
 Time 5.03 h
 INSTRUM spect
 PROBHD Z108618_0432 (
 PULPROG noesygpph
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 16
 SWH 4084.967 Hz
 FIDRES 3.989226 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 D0 0.00010266 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec
 TDAV 1
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.50 usec
 P2 31.00 usec
 P17 2500.00 usec
 PLW1 11.99499989 W
 PLW10 4.26300001 W
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FnmODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440082 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440082 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0



Current Data Parameters
NAME 27 HSQC
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20161122
Time 4.34 h
INSTRUM spect
PROBHD Z108618_0432 4
PULPROG hsqcetgpa1sp2.3
TD 1024
SOLVENT CDCl3
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 12.520032 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNS12 145.0000000
CNS17 -0.5000000
D0 0.00000300 sec
D1 1.50000000 sec
D4 0.00172414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.003606000 sec
D24 0.00089000 sec
IN0 0.0003010 sec
TDav 1
SFO1 400.1458807 MHz
NUC1 1H
P1 15.50 usec
P2 31.00 usec
P28 1000.00 usec
PLW1 11.99499989 W
SFO2 100.6233320 MHz
NUC2 13C
CPDPRG2 b1_p5m4sp_4sp.2
P3 10.40 usec
P14 500.00 usec
P24 2000.00 usec
P31 1300.00 usec
P63 1500.00 usec
PLW0 0 W
PLW2 50.00299835 W
PLW2 0.84504998 W
SPNAM[3] Crp60,0.5,20.1
SPOAL3 0.500
SPOFFS3 0 Hz
SPW3 8.26329994 W
SPNAM[7] Crp60comp.4
SPOAL7 0.500
SPOFFS7 0 Hz
SPW7 8.26329994 W
SPNAM[14] Crp32,1.5,20.2
SPOAL14 0.500
SPOFFS14 0 Hz
SPW14 3.52570009 W
SPNAM[18] Crp60_xfillt.2
SPOAL18 0.500
SPOFFS18 0 Hz
SPW18 1.98000002 W
SPNAM[31] Crp32,1.5,20.2
SPOAL31 0.500
SPOFFS31 0 Hz
SPW31 0.88142002 W
GPNAM[1] SMSQ10.100
GPZ1 80.00 %
GPNAM[2] SMSQ10.100
GPZ2 20.10 %
GPNAM[3] SMSQ10.100
GPZ3 11.00 %
GPNAM[4] SMSQ10.100
GPZ4 -5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 128
SFO1 100.6233 MHz
FIDRES 129.775742 Hz
SW 165.084 ppm
FMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

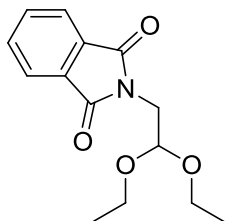
F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162890 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0



Current Data Parameters
NAME zs-2-102-1H
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20170315
Time 15.56 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zg30
TD 32768
SOLVENT CDCl3
NS 16
DS 2
SWH 7211.539 Hz
FIDRES 0.440157 Hz
AQ 2.2719147 sec
RG 128
DW 69.333 usec
DE 6.50 usec
TE 300.0 K
D1 0.50000000 sec
TD0 1
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

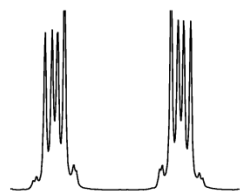
F2 - Processing parameters
SI 32768
SF 400.1440000 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



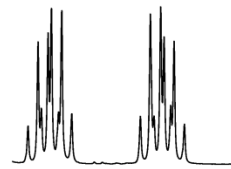
7.86
7.85
7.85
7.84
7.72
7.72
7.71
7.70
7.26

4.90
4.88
4.87
3.84
3.82
3.77
3.75
3.75
3.74
3.73
3.72
3.71
3.70
3.58
3.56
3.55
3.54
3.52
3.52
3.50

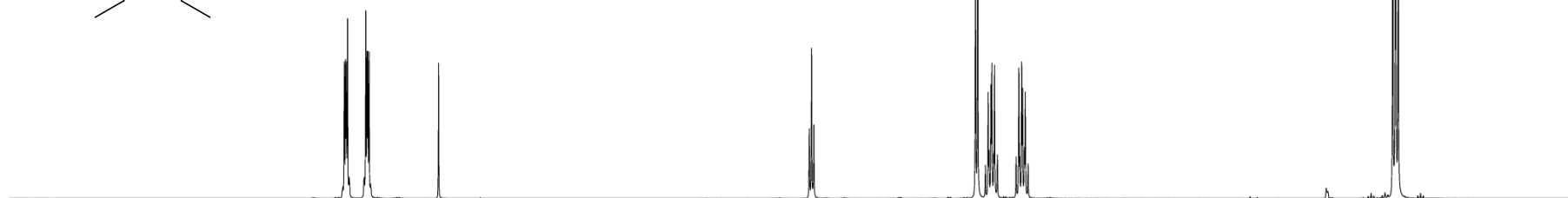
1.17
1.16
1.14



7.8 ppm



3.6 ppm



9

8

7

6

5

4

3

2

1

ppm

1.88
1.99

1.00

2.07
2.09
2.08

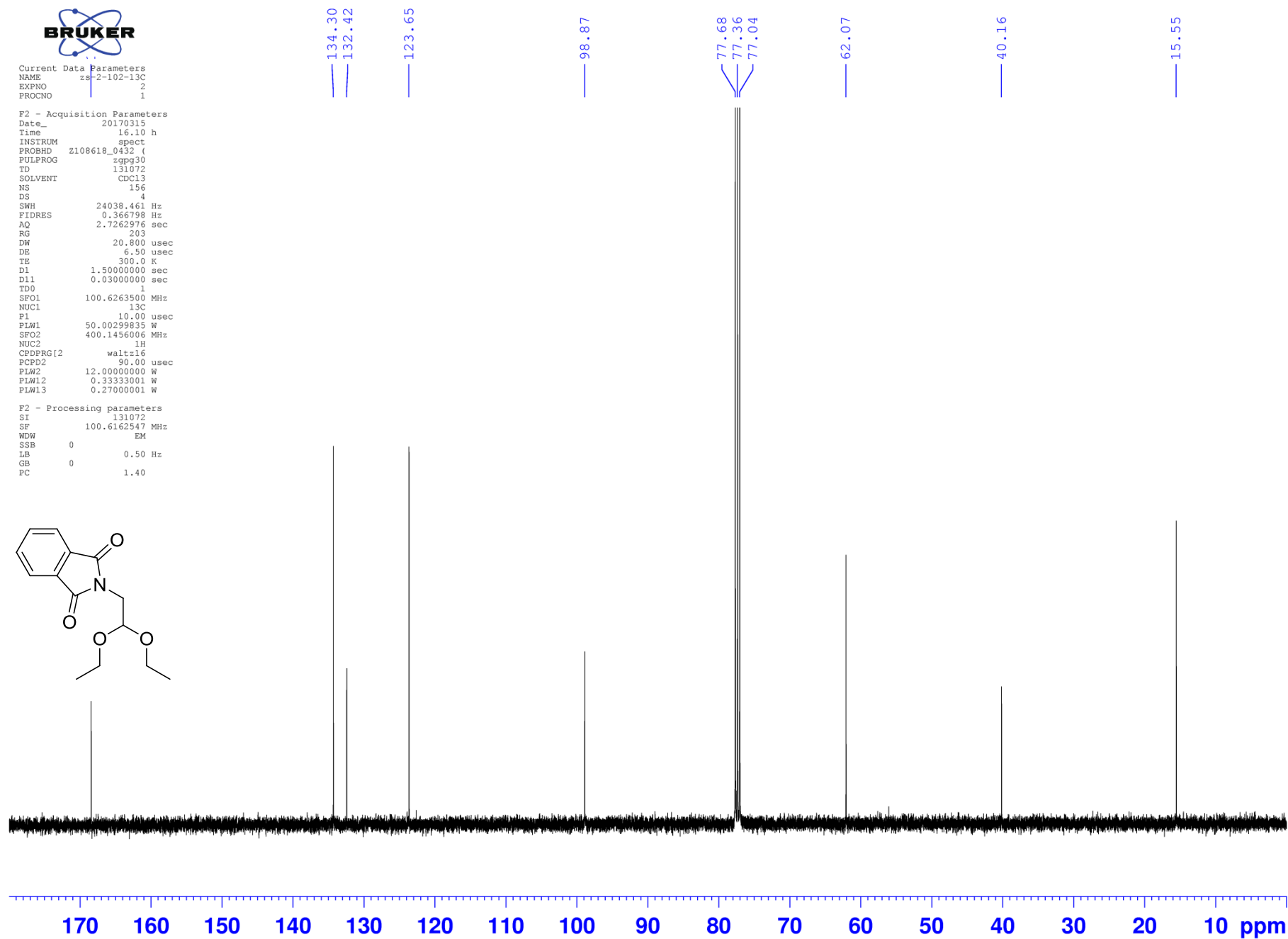
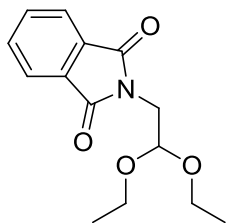
6.09



Current Data Parameters
NAME zs-2-102-13C
EXPNO 2
PROCNO 1

F2 - Acquisition Parameters
Date_ 20170315
Time 16.10 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zgpg30
TD 131072
SOLVENT CDCl3
NS 156
DS 4
SWH 24038.461 Hz
FIDRES 0.366798 Hz
AQ 2.7262976 sec
RG 203
DW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG[2] waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162547 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.40



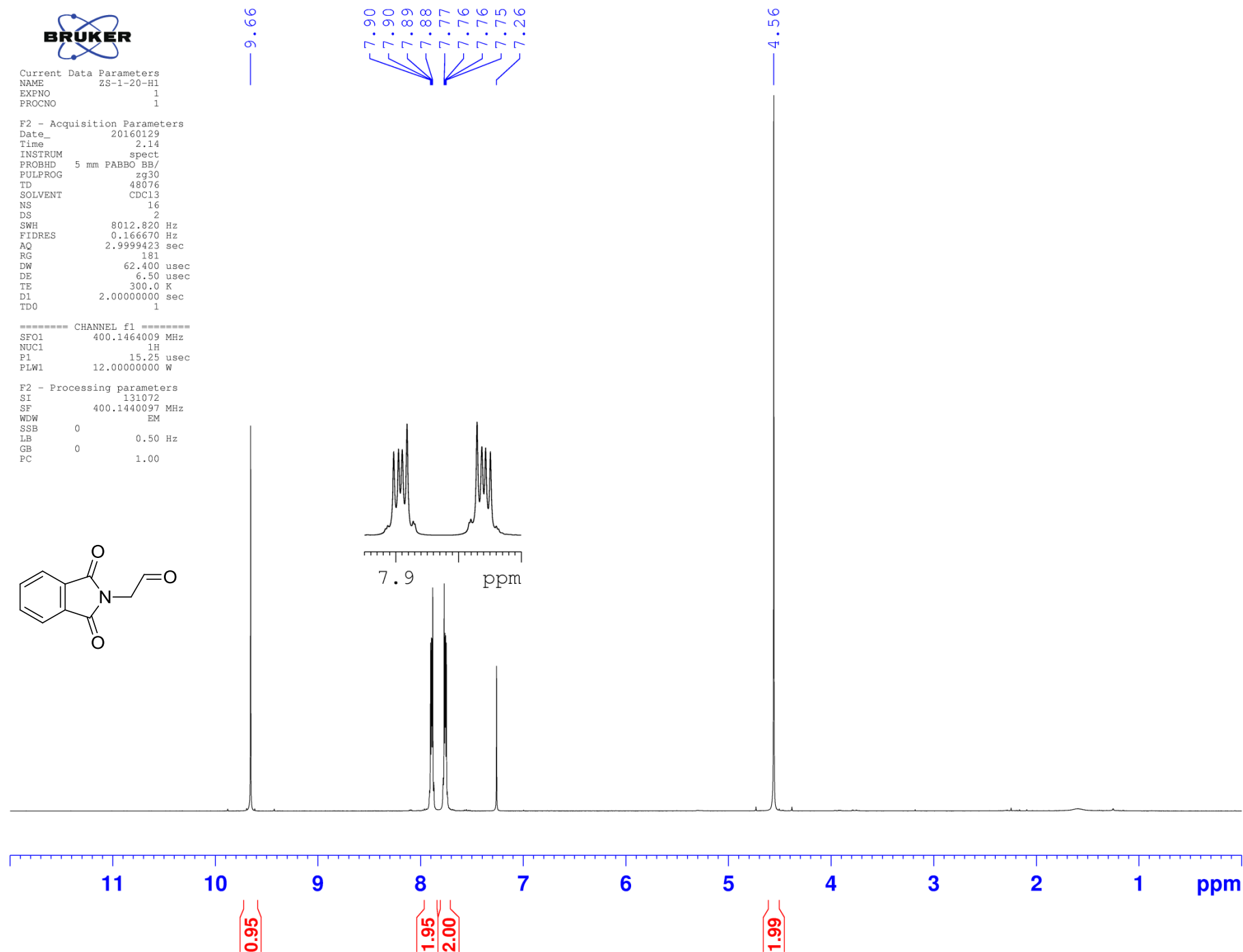
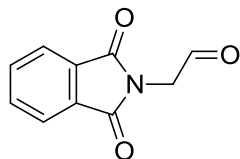


Current Data Parameters
NAME ZS-1-20-H1
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160129
Time 2.14
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDC13
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 181
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440097 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00





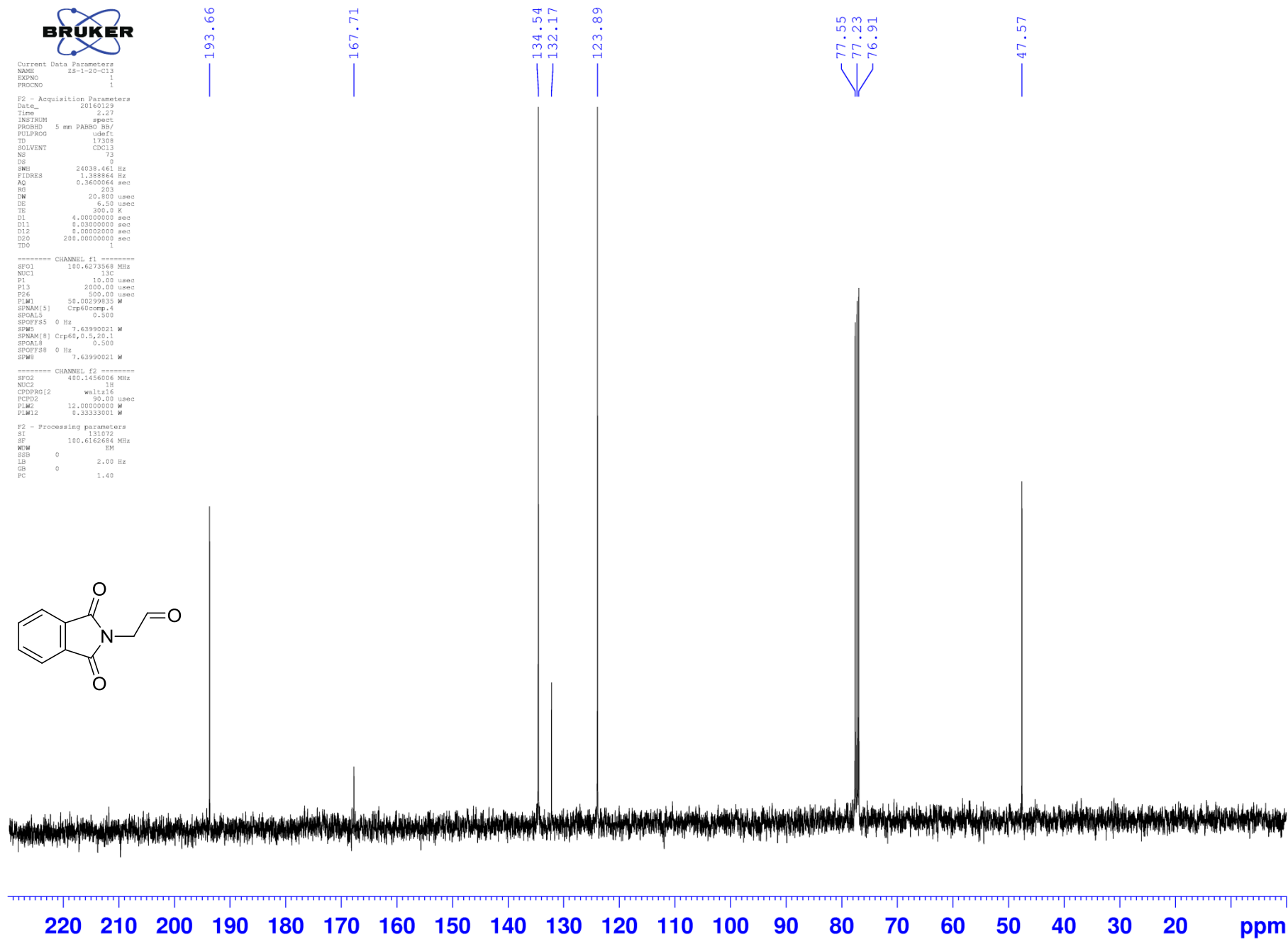
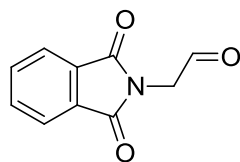
Current Data Parameters
NAME ZS-1-20-C13
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160129
Time 2.27
INSTRUM spect
PROBHD 5 mm PARBO BB/
PULPROG udefc
TD 17398
SOLVENT CDCl3
NS 73
DS 0
SWH 24038.461 Hz
FIDRES 1.388864 Hz
AQ 0.3600064 sec
RG 203
RW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 4.00000000 sec
D11 0.03000000 sec
D12 0.00000000 sec
D20 200.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6273568 MHz
NUC1 13C
P1 10.00 usec
P13 2000.00 usec
P26 500.00 usec
PLW1 50.00299835 W
SPNAM[5] Crp60comp.4
SFOAL5 0 Hz
SFOFF5 0 Hz
SPW5 7.63990021 W
SPNAM[8] Crp60,0.5,20.1
SFOAL8 0.500
SFOFF8 0 Hz
SPW8 7.63990021 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG[2] waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W

F2 - Processing parameters
SI 131072
SF 100.6162684 MHz
WDW EM
SSB 0
LB 2.00 Hz
GB 0
PC 1.40



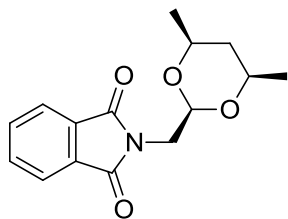


Current Data Parameters
NAME zs-1-25-1H
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160201
Time 2.35
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDC13
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 144
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

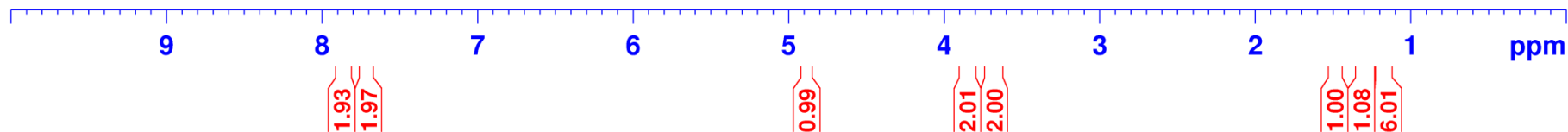
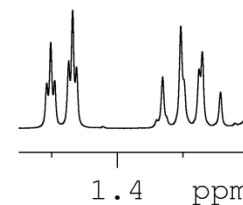
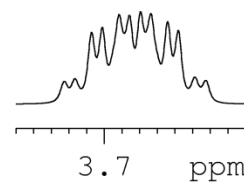
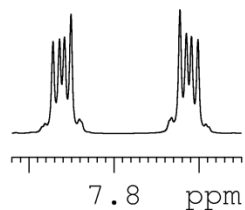
F2 - Processing parameters
SI 131072
SF 400.1440097 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00



7.88
7.87
7.86
7.86
7.85
7.84
7.73
7.72
7.71
7.71
7.70
7.69
7.26

4.90
4.88
4.87
3.86
3.84
3.72
3.72
3.71
3.70
3.69
3.69
3.68
3.67
3.66
3.66
3.65
3.64

1.51
1.50
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1.30
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1.27
1.24
1.18
1.17





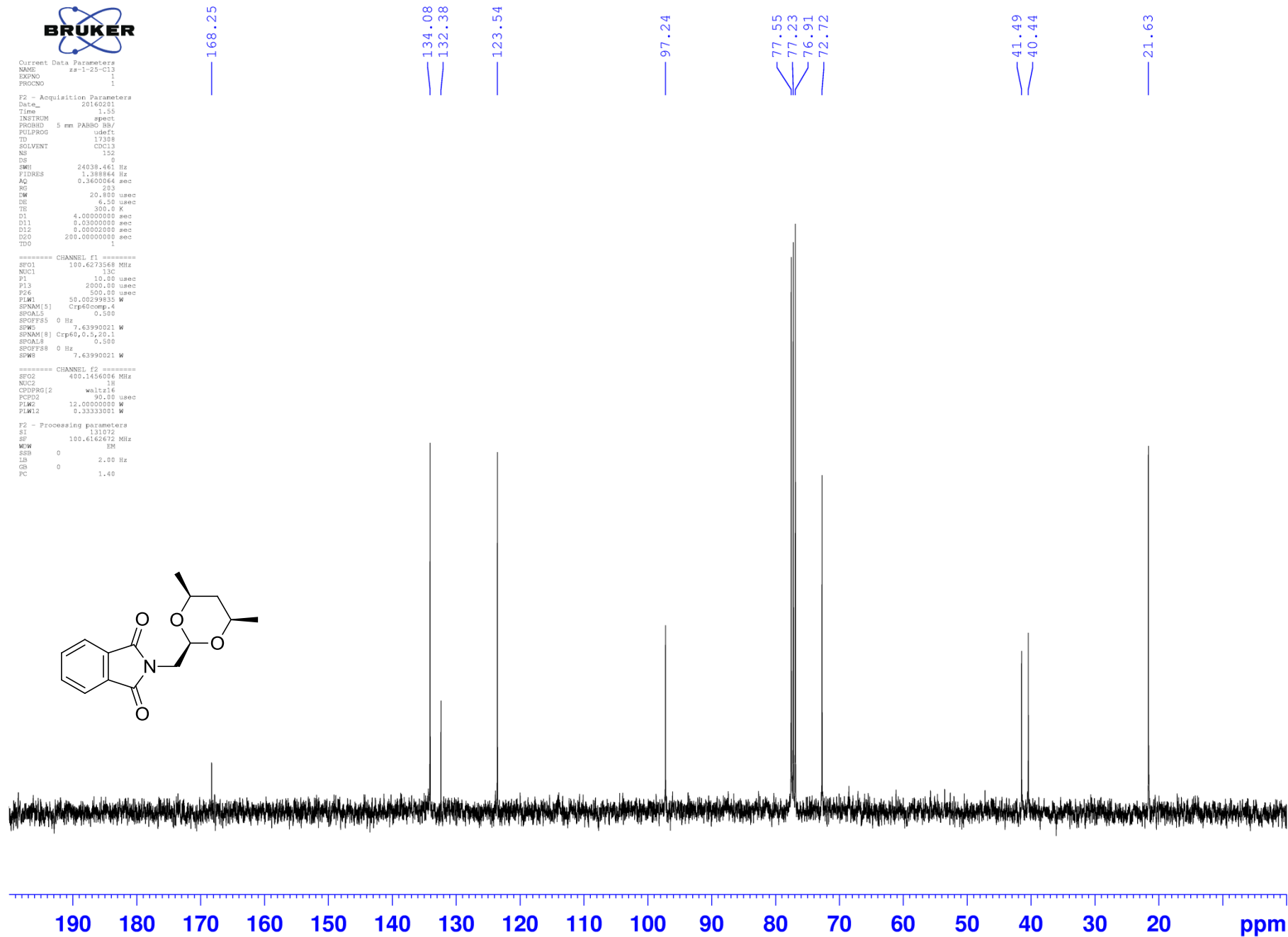
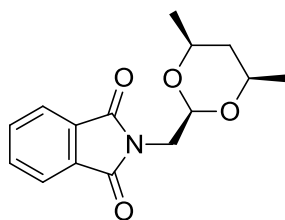
Current Data Parameters
NAME rs-1-25-C13
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160201
Time 1.55
INSTRUM spect
PROBHD 5 mm PARBO BB/
PULPROG udefc
TD 17388
SOLVENT CDCl3
NS 152
DS 0
SWH 24038.461 Hz
FIDRES 1.388864 Hz
AQ 0.3600064 sec
RG 203
RW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 4.00000000 sec
D11 0.03000000 sec
D12 0.00000000 sec
D20 200.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6273568 MHz
NUC1 13C
P1 10.00 usec
P13 2000.00 usec
P26 500.00 usec
PLW1 50.00299835 W
SPNAM[5] Crp60comp.4
SFOAL5 0 Hz
SFOFFS 0 Hz
SPW5 7.63990021 W
SPNAM[8] Crp60,0.5,20.1
SFOAL8 0.500
SFOFFS8 0 Hz
SPW8 7.63990021 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPOPRG[2] waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W

F2 - Processing parameters
SI 131072
SF 100.6162672 MHz
WDW EM
SSB 0
LB 2.00 Hz
GB 0
PC 1.40



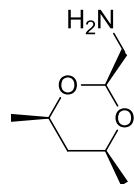


Current Data Parameters
NAME zs-1-26-H1-diluted
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160202
Time 21.08
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDC13
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 181
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440098 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00

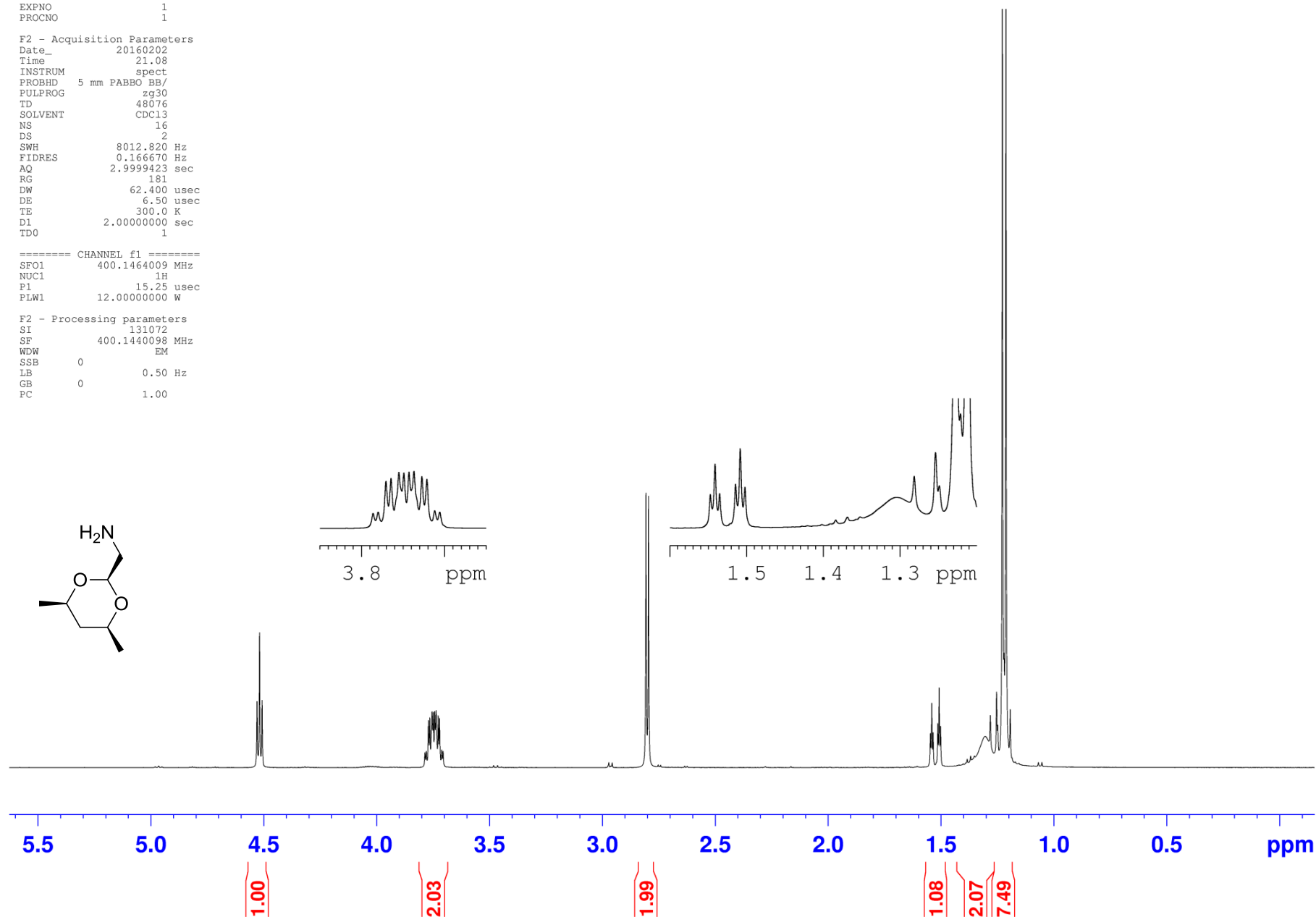


4.53
4.52
4.51

3.79
3.78
3.77
3.76
3.75
3.74
3.73
3.72
3.71
3.71

2.81
2.80

1.55
1.54
1.54
1.51
1.51
1.50
1.30
1.28
1.25
1.25
1.23
1.22
1.21
1.19





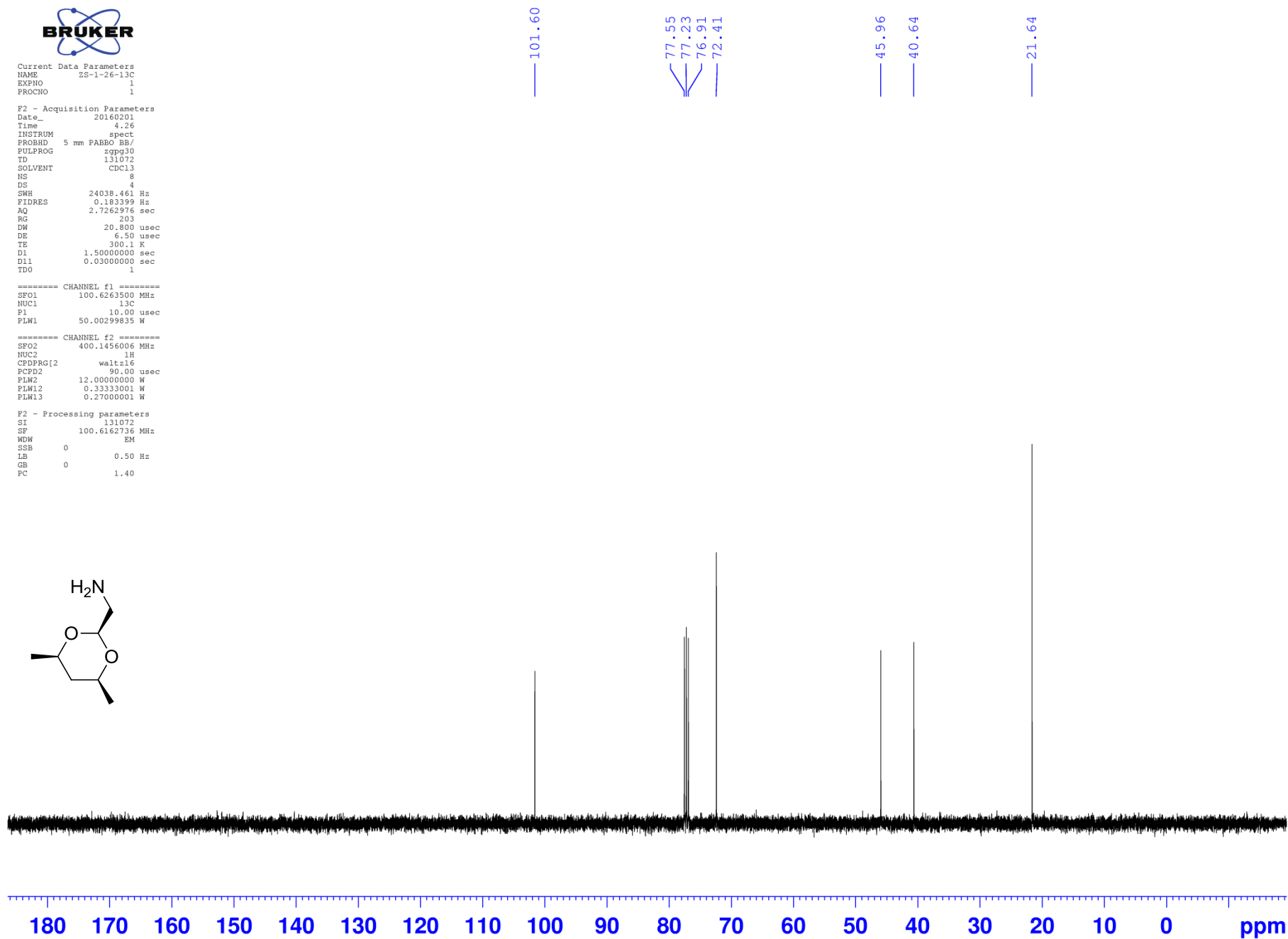
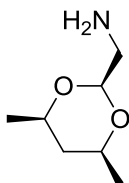
Current Data Parameters
NAME 25-1-26-13C
EXPHO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160201
Time 4.26
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zgpg30
TD 131072
SOLVENT CDCl3
NS 8
DS 4
SWH 24038.461 Hz
FIDRES 0.183399 Hz
AQ 2.7262976 sec
RG 203
DW 20.800 usec
DE 6.50 usec
TE 300.1 K
D1 1.50000000 sec
D11 0.03000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6263500 MHz
NUC1 13C
P1 10.00 usec
PLW1 50.00299835 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W
PLW13 0.27000001 W

F2 - Processing parameters
SI 131072
SF 100.6162736 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.40



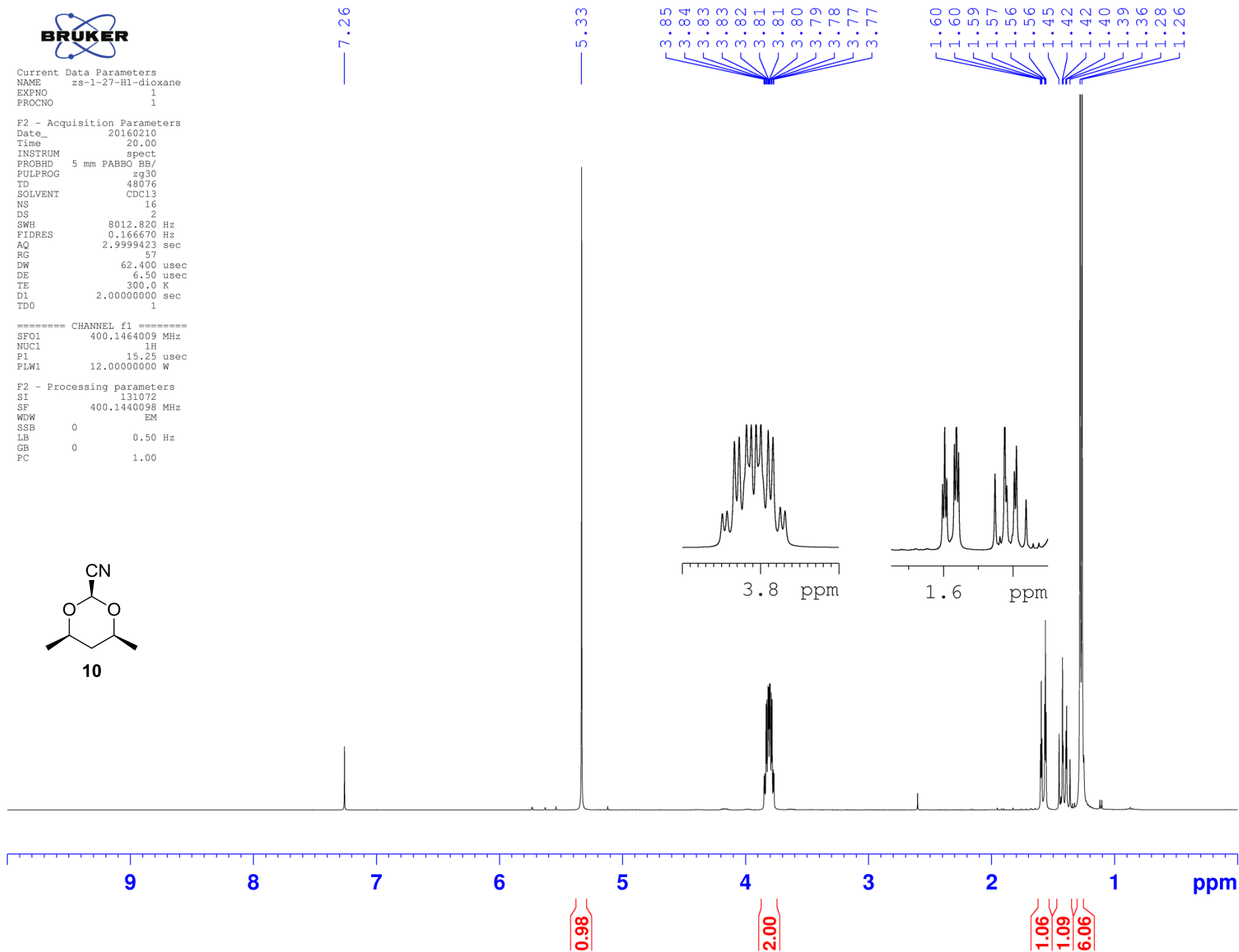
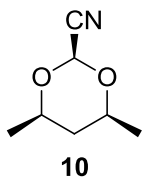


Current Data Parameters
NAME zs-1-27-H1-dioxane
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160210
Time 20.00
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 48076
SOLVENT CDC13
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.166670 Hz
AQ 2.9999423 sec
RG 57
DW 62.400 usec
DE 6.50 usec
TE 300.0 K
D1 2.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 131072
SF 400.1440098 MHz
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00





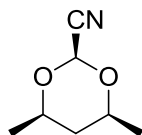
Current Data Parameters
NAME za-1-27-C13-dioxane
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160210
Time 20.10
INSTRUM spect
PROBHD 5 mm PARBO BB/
PULPROG udefc
TD 17398
SOLVENT CDCl3
NS 40
DS 0
SWH 24038.461 Hz
FIDRES 1.388864 Hz
AQ 0.3600064 sec
RG 203
RW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 4.00000000 sec
D11 0.03000000 sec
D12 0.00000000 sec
D20 200.00000000 sec
TD0 1

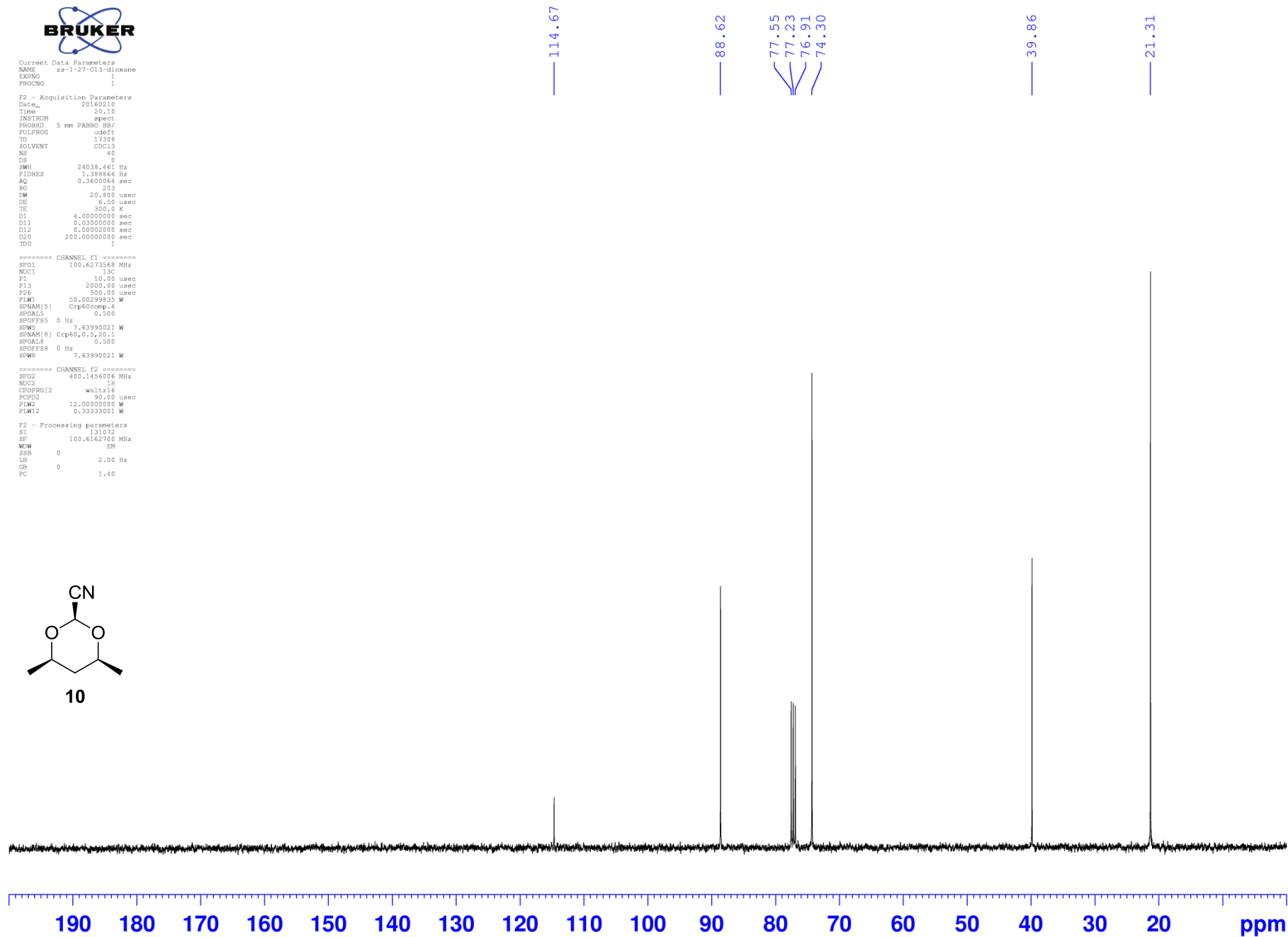
===== CHANNEL f1 =====
SFO1 100.6273568 MHz
NUC1 13C
P1 10.00 usec
P13 2000.00 usec
P26 500.00 usec
PLW1 50.00299835 W
SPNAM[5] Crp60comp.4
SFOAL5 0 Hz
SFOFFS 0 Hz
SPW5 7.63990021 W
SPNAM[8] Crp60,0.5,20.1
SFOAL8 0 Hz
SFOFF8 0 Hz
SPW8 7.63990021 W

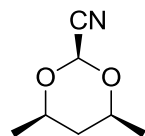
===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG[2] waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W

F2 - Processing parameters
SI 131072
SF 100.6162700 MHz
WDW EM
SSB 0
LB 2.00 Hz
GB 0
PC 1.40

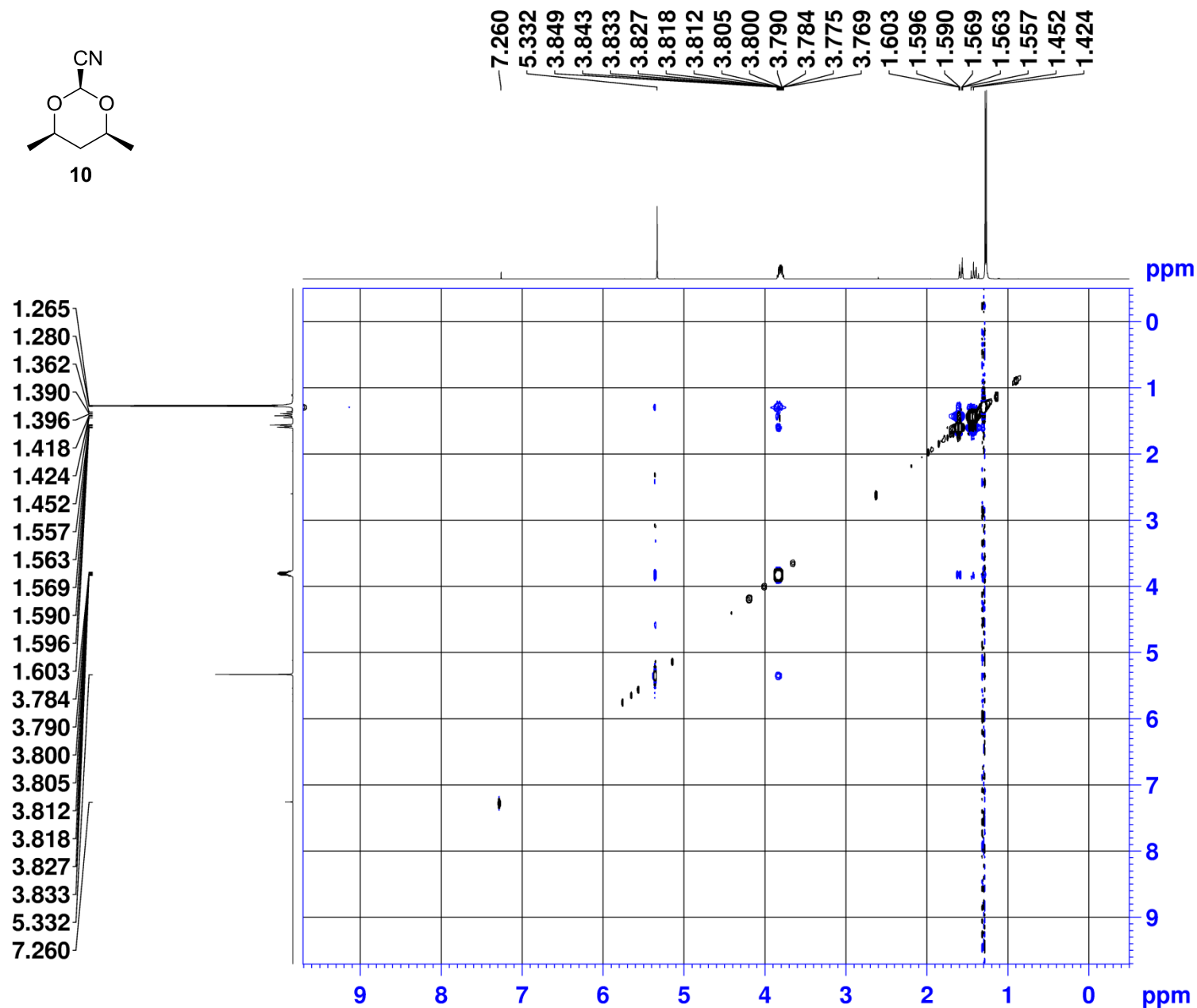


10





10



Current Data Parameters
NAME zs-1-27-HNOESY-dioxane
EXPNO 1
PROCNO 1

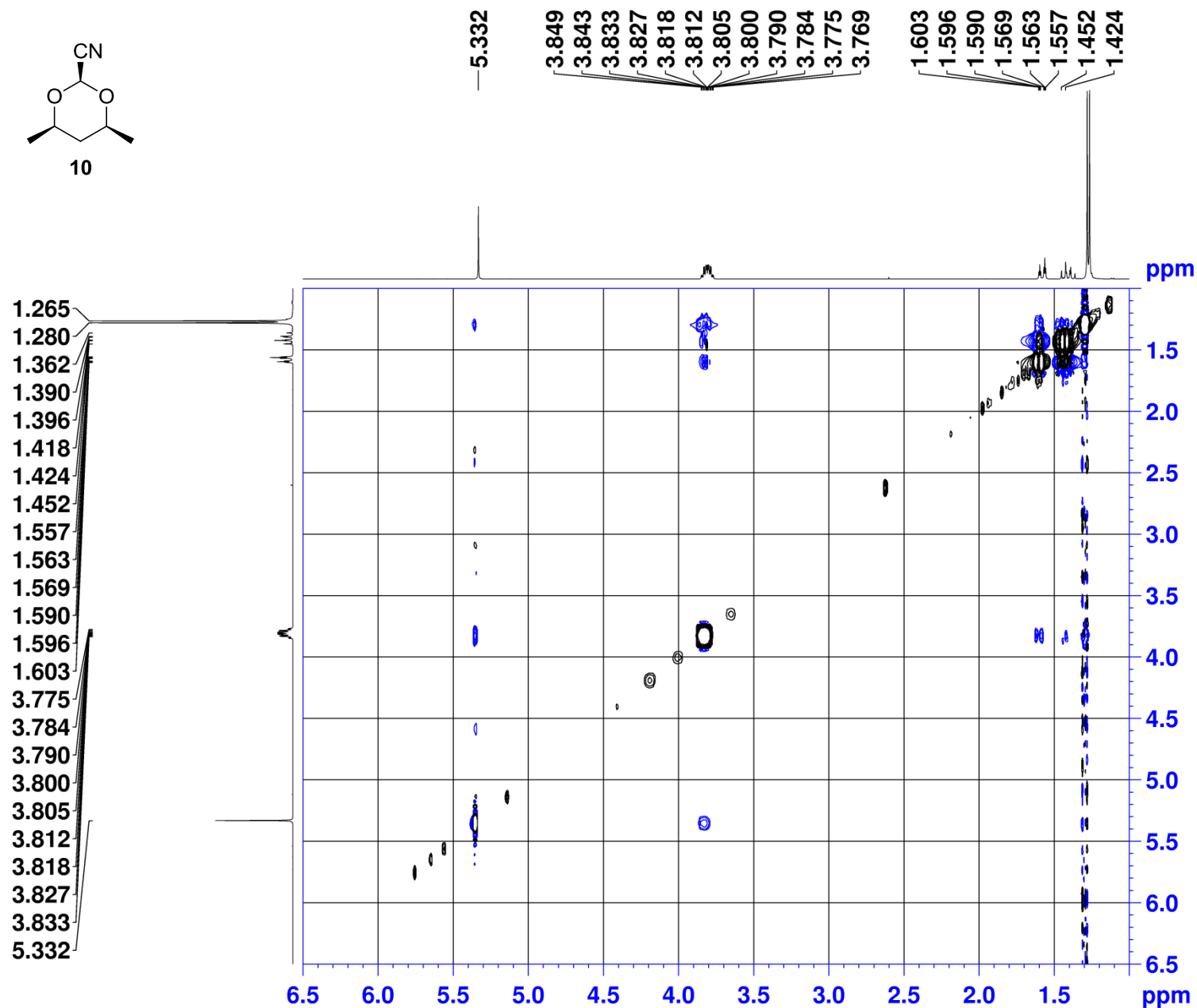
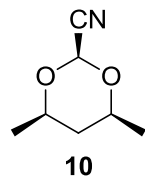
F2 - Acquisition Parameters
Date_ 20160210
Time 20.30
INSTRUM spect
PROBHD 5 mm FABBO BB/
PULPROG noesygpphpg
TD 2048
SOLVENT CDCl3
NS 4
DS 32
SWH 4084.967 Hz
FIDRES 1.994613 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
DO 0.00010330 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec

===== CHANNEL f1 =====
SFO1 400.1458419 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P17 2500.00 usec
PLW1 12.00000000 W
PLW10 3.99410009 W
===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0



Current Data Parameters
 NAME zs-1-27-HNOESY-dioxane
 EXPNO 1
 PROCNO 1

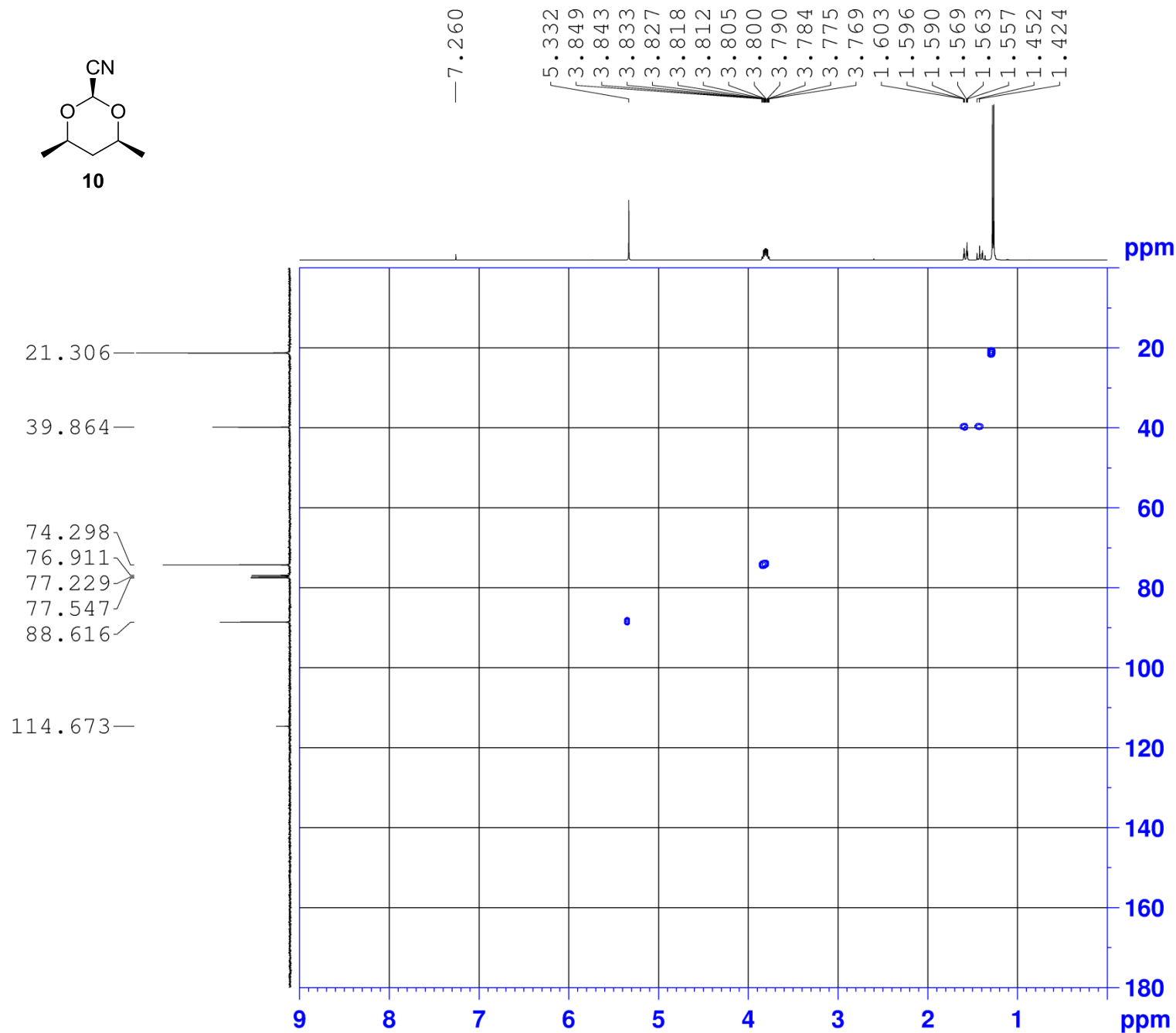
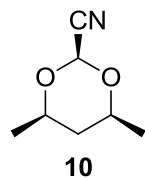
F2 - Acquisition Parameters
 Date_ 20160210
 Time 20.30
 INSTRUM spect
 PROBHD 5 mm FABBO BB/
 PULPROG noesygpgppp
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 32
 SWH 4084.967 Hz
 FIDRES 1.994613 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 DO 0.00010330 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 INO 0.00024480 sec

===== CHANNEL f1 =====
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.00 usec
 P2 30.00 usec
 P17 2500.00 usec
 PLW1 12.00000000 W
 PLW10 3.99410009 W
 ===== GRADIENT CHANNEL =====
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FhMODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0



Current Data Parameters
NAME zs-1-27-HSQC-dioxane
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160210
Time 20.13
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG haqcddetgsp2.3
TD 1024
SOLVENT CDCl3
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.1 K
CNS12 145.000000
CNS117 -0.500000
D0 0.00000000 sec
D1 1.50000000 sec
D4 0.0012414 sec
D11 0.03000000 sec
D16 0.00200000 sec
D21 0.00360000 sec
D24 0.00089000 sec
INO 0.00003010 sec

===== CHANNEL f1 =====
SFO1 400.1458807 MHz
NUC1 13C
P1 15.25 usec
P2 30.50 usec
P18 1000.00 usec
PLW1 12.00000000 W

===== CHANNEL f2 =====
SFO2 100.6233320 MHz
NUC2 13C
CPDPRG2 bi_p5m4p4p-2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1900.00 usec
P63 1500.00 usec
PLW2 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SPOAL3 0.500
SPOFS3 0 Hz
SPW3 7.63940001 W
SPNAM[7] Crp60comp,4
SPOAL7 0.500
SPOFS7 0 Hz
SPW7 7.63940001 W
SPNAM[14] Crp32,1.5,20.2
SPOAL14 0.500
SPOFS14 0 Hz
SPW14 3.25950003 W
SPNAM[18] Crp60_xf11c,2
SPOAL18 0.500
SPOFS18 0 Hz
SPW18 1.83050001 W
SPNAM[31] Crp32,1.5,20.2
SPOAL31 0.500
SPOFS31 0 Hz
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPNAM[3] SMSQ10.100
GPNAM[4] SMSQ10.100
GP21 80.00 %
GP22 20.10 %
GP23 11.00 %
GP24 -5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 128
SFO1 100.6233 MHz
FIDRES 129.775742 Hz
SW 165.084 ppm
FMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WFW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.612890 MHz
WFW QSINE
SSB 2
LB 0 Hz
GB 0

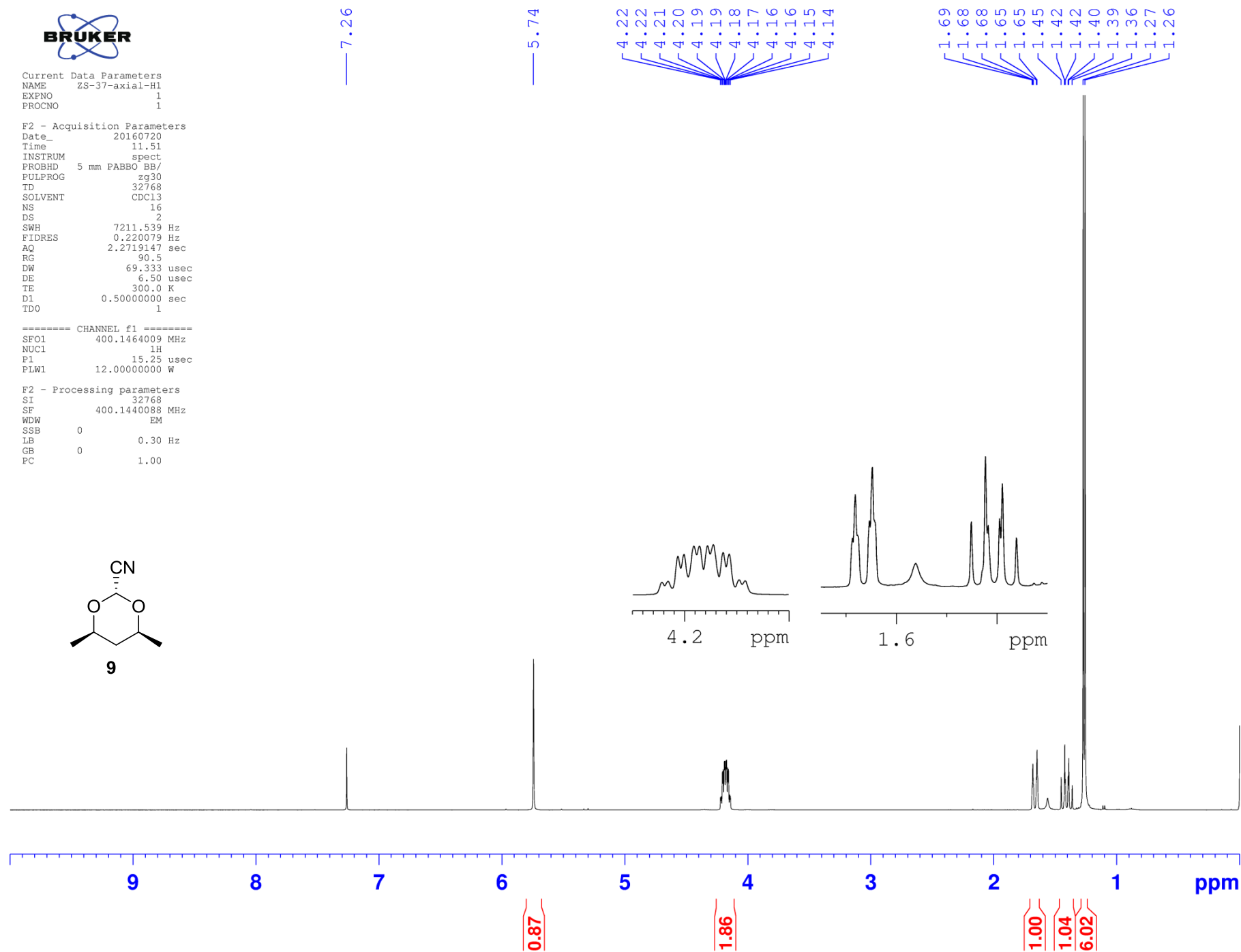
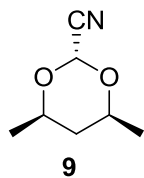


Current Data Parameters
NAME ZS-37-axial-H1
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160720
Time 11.51
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG zg30
TD 32768
SOLVENT CDCl3
NS 16
DS 2
SWH 7211.539 Hz
FIDRES 0.220079 Hz
AQ 2.2719147 sec
RG 90.5
DW 69.333 usec
DE 6.50 usec
TE 300.0 K
D1 0.50000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 32768
SF 400.1440088 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00





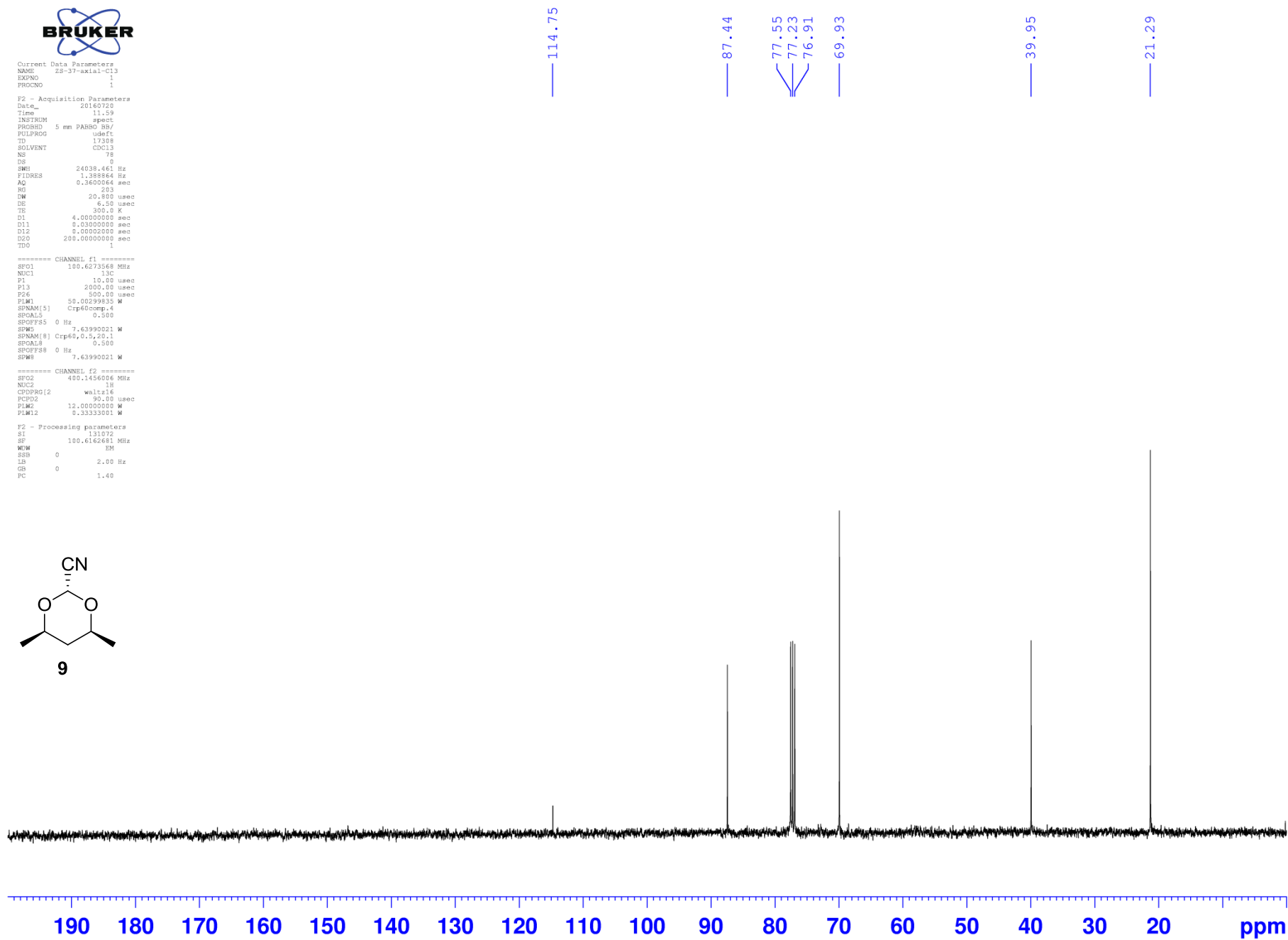
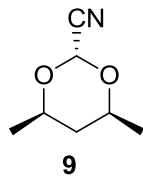
Current Data Parameters
NAME ZS-37-axial-C13
EXPNO 1
PROCNO 1

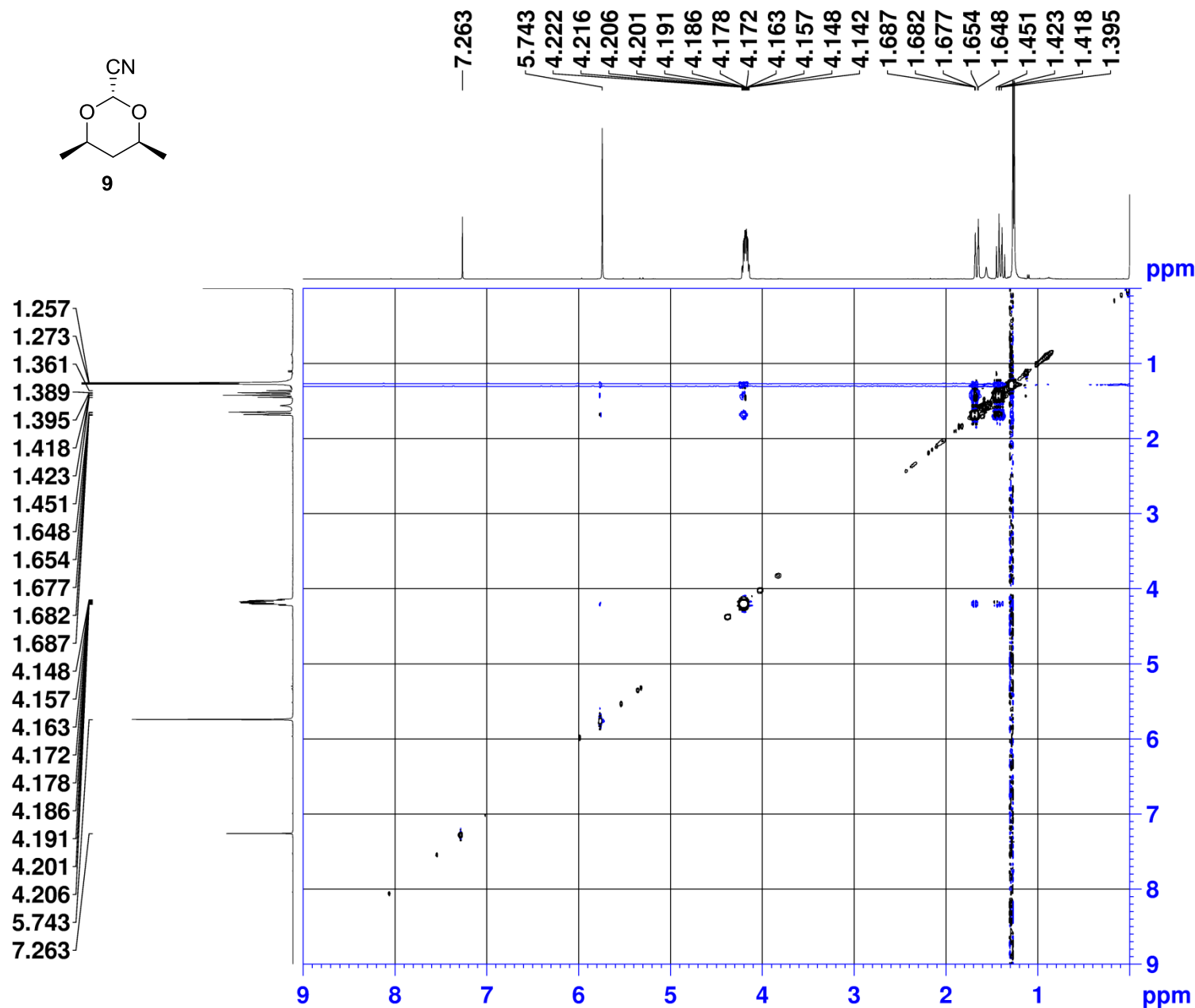
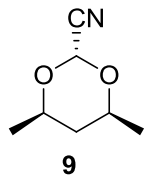
F2 - Acquisition Parameters
Date_ 20160720
Time 11.59
INSTRUM spect
PROBHD 5 mm PARBO BB/
PULPROG udefc
TD 17398
SOLVENT CDCl3
NS 78
DS 0
SWH 24038.461 Hz
FIDRES 1.388864 Hz
AQ 0.3600064 sec
RG 203
RW 20.800 usec
DE 6.50 usec
TE 300.0 K
D1 4.00000000 sec
D11 0.03000000 sec
D12 0.00020000 sec
D20 200.00000000 sec
TD0 1

===== CHANNEL f1 =====
SFO1 100.6273568 MHz
NUC1 13C
P1 10.00 usec
P13 2000.00 usec
P26 500.00 usec
PLW1 50.00299835 W
SPNAM[5] Crp60comp.4
SFOAL5 0 Hz 0.500
SFOFF5 0 Hz
SPW5 7.63990021 W
SPNAM[8] Crp60,0.5,20.1
SFOAL8 0 Hz 0.500
SFOFF8 0 Hz
SPW8 7.63990021 W

===== CHANNEL f2 =====
SFO2 400.1456006 MHz
NUC2 1H
CPOPRG[2] waltz16
PCPD2 90.00 usec
PLW2 12.00000000 W
PLW12 0.33333001 W

F2 - Processing parameters
SI 131072
SF 100.6162681 MHz
WDW EM
SSB 0
LB 2.00 Hz
GB 0
PC 1.40





Current Data Parameters
 NAME ZS-1-37-AXIAL-HNOESY
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20160720
 Time 20.39
 INSTRUM spect
 PROBHD 5 mm FABBO BB/
 PULPROG noesygpgppp
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 16
 SWH 4084.967 Hz
 FIDRES 1.994613 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 D0 0.00010266 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 INO 0.00024480 sec

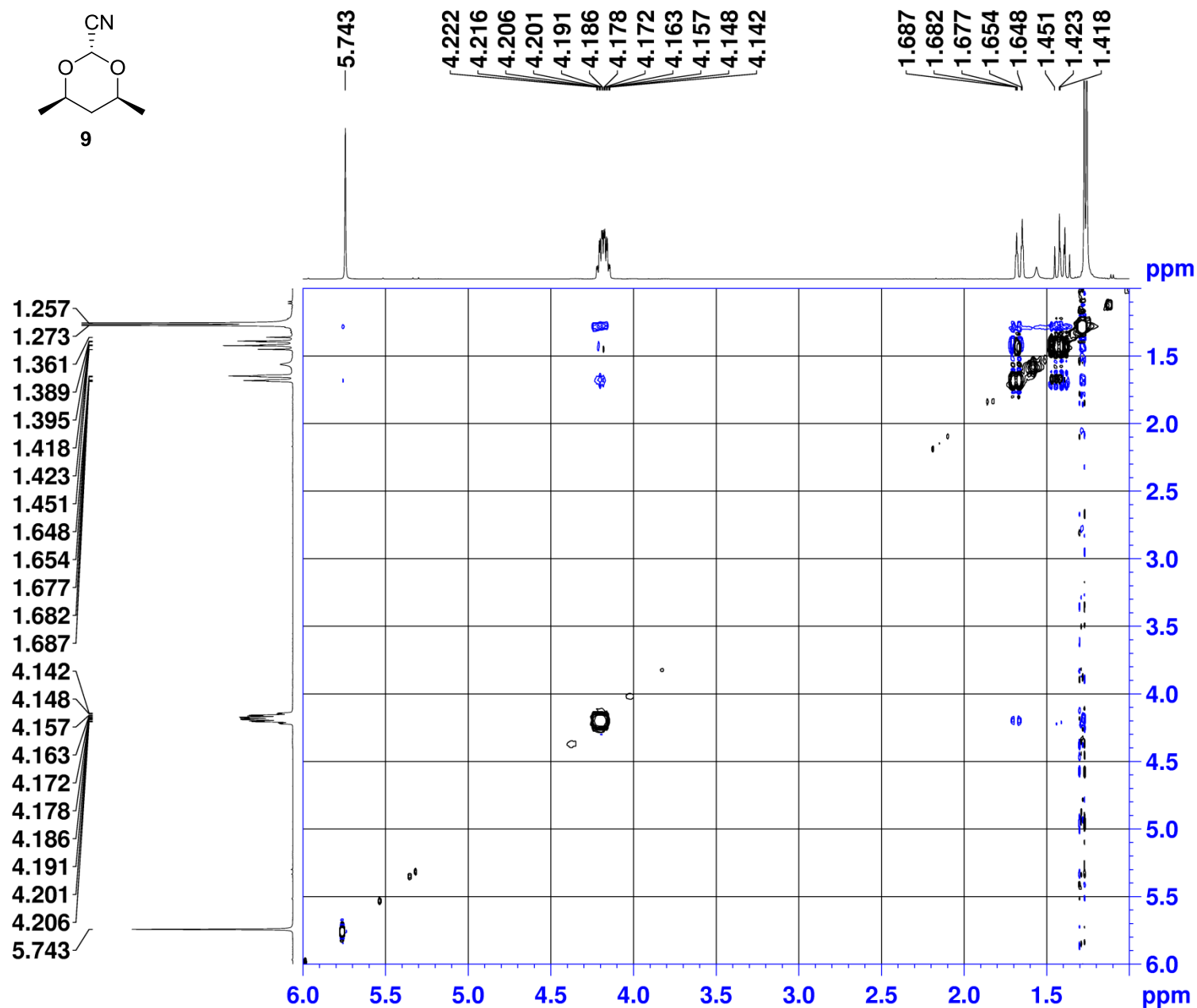
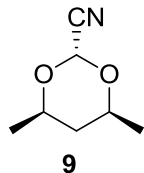
===== CHANNEL f1 =====
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.50 usec
 P2 31.00 usec
 P17 2500.00 usec
 PLW1 11.99499989 W
 PLW10 4.26300001 W

===== GRADIENT CHANNEL =====
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FhMODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0



Current Data Parameters
 NAME ZS-1-37-AXIAL-HNOESY
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20160720
 Time 20.39
 INSTRUM spect
 PROBHD 5 mm FABBO BB/
 PULPROG noesygpphpg
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 16
 SWH 4084.967 Hz
 FIDRES 1.994613 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 D0 0.00010266 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00002000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec

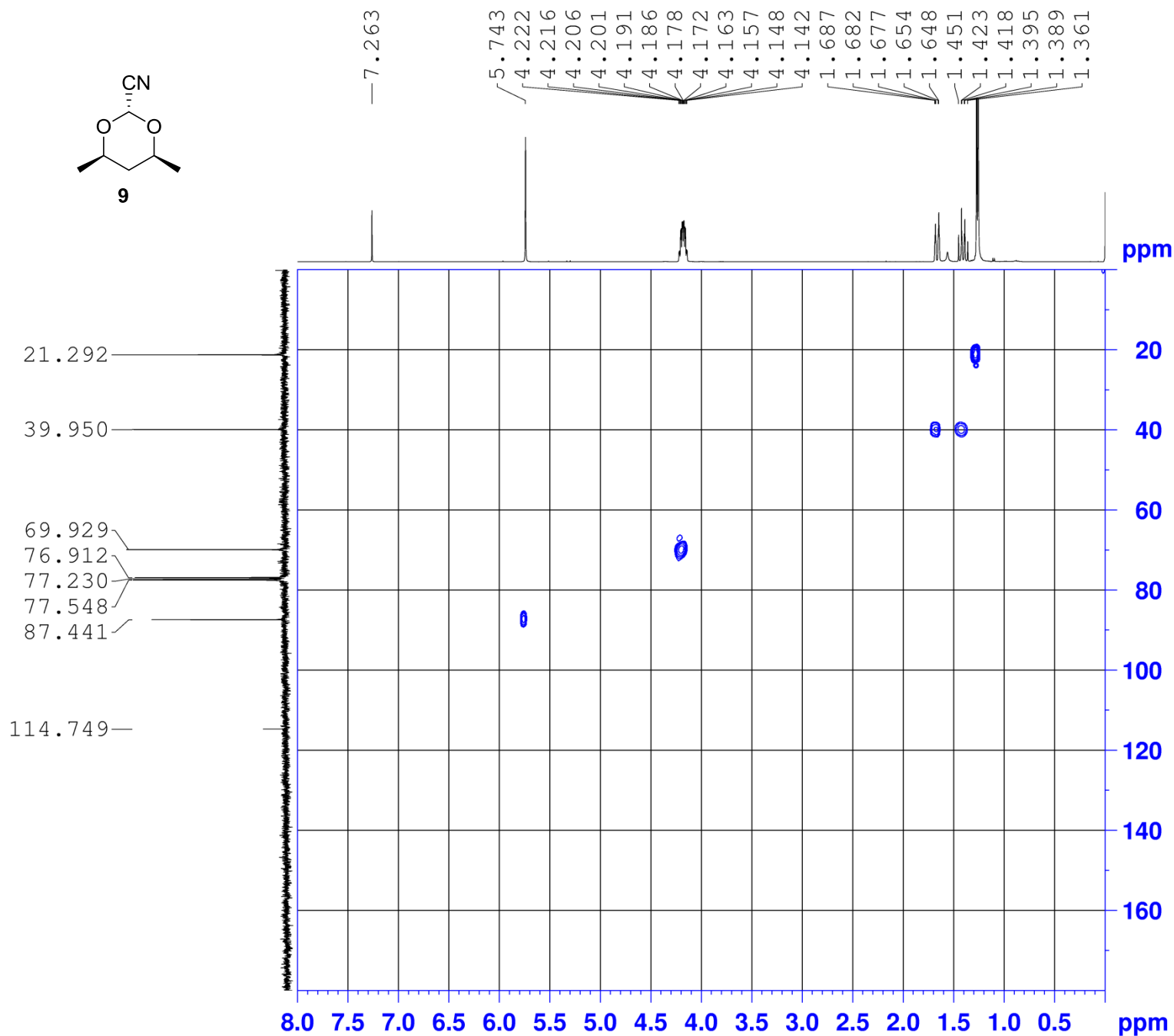
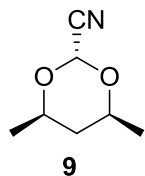
===== CHANNEL f1 =====
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.50 usec
 P2 31.00 usec
 P17 2500.00 usec
 PLW1 11.99499989 W
 PLW10 4.26300001 W

===== GRADIENT CHANNEL =====
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FnmODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0



Current Data Parameters
NAME Z8-37-axial-HSQC
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20160720
Time 12.05
INSTRUM spect
PROBHD 5 mm PABBO BB/
PULPROG haqcetdeta1sp2.3
TD 1328
SOLVENT CDCl3
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 6.260016 Hz
AQ 0.0798720 sec
RG 203
DW 78.000 usec
DE 6.50 usec
TE 300.0 K
CNS12 145.0000000
CNS117 -0.5000000
DO 0.00000300 sec
D1 1.50000000 sec
D4 0.00172414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.00340000 sec
D24 0.00089000 sec
INO 0.00003010 sec

===== CHANNEL f1 =====
SF01 400.1458807 MHz
NUC1 1H
P1 15.25 usec
P2 30.50 usec
P28 1000.00 usec
PLW1 12.00000000 W

===== CHANNEL f2 =====
SF02 100.6233320 MHz
NUC2 13C
CPDPRG2 bi_p5m4sp_4sp.2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1900.00 usec
P63 1500.00 usec
PLW0 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SFOAL3 0.500
SPOFFS3 0 Hz
SPW3 7.63940001 W
SPNAM[7] Crp60comp.4
SFOAL7 0.500
SPOFFS7 0 Hz
SPW7 7.63940001 W
SPNAM[14] Crp32,1.5,20.2
SFOAL14 0.500
SPOFFS14 0 Hz
SPW14 3.25950003 W
SPNAM[18] Crp60_xfilt.2
SFOAL18 0.500
SPOFFS18 0 Hz
SPW18 1.83050001 W
SPNAM[31] Crp32,1.5,20.2
SFOAL31 0.500
SPOFFS31 0 Hz
SPW31 0.81487000 W

===== GRADIENT CHANNEL =====
GPNAM[1] SMSQ10.100
GPNAM[2] SMSQ10.100
GPNAM[3] SMSQ10.100
GPNAM[4] SMSQ10.100
GP21 80.00 %
GP22 20.10 %
GP23 11.00 %
GP24 5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 70
SF01 100.6233 MHz
FIDRES 237.304230 Hz
SW 165.084 ppm
FMODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDM QSIINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

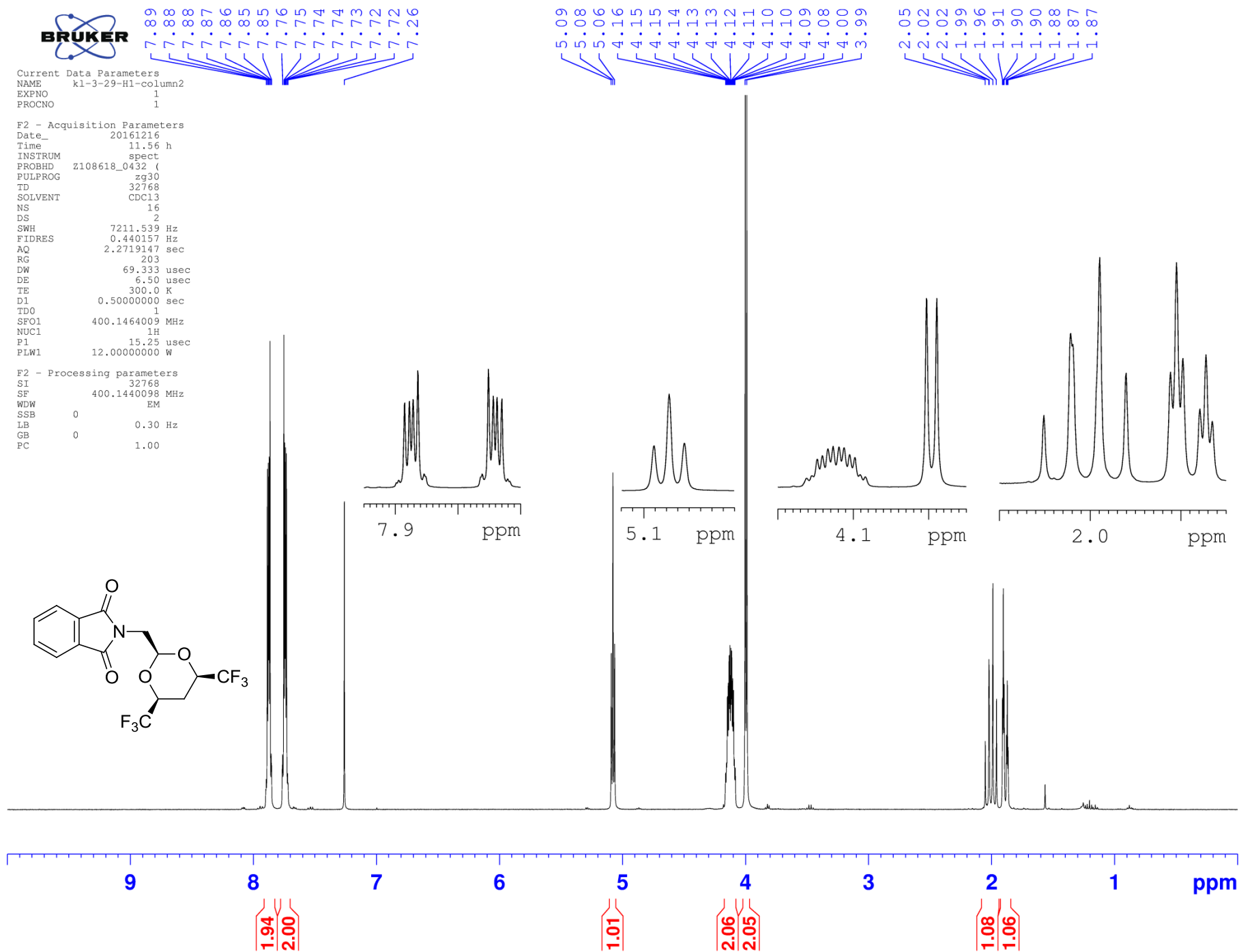
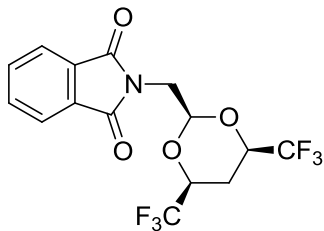
F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162890 MHz
WDM QSIINE
SSB 2
LB 0 Hz
GB 0



Current Data Parameters
NAME k1-3-29-H1-column2
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20161216
Time 11.56 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zg30
TD 32768
SOLVENT CDCl3
NS 16
DS 2
SWH 7211.539 Hz
FIDRES 0.440157 Hz
AQ 2.2719147 sec
RG 203
DW 69.333 usec
DE 6.50 usec
TE 300.0 K
D1 0.50000000 sec
TD0 1
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 32768
SF 400.1440098 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

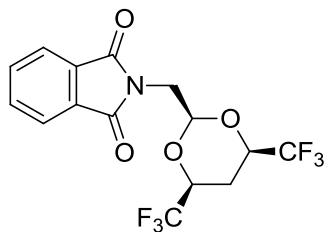




Current Data Parameters
NAME: k1-3-23-C13-column2
EXPNO: 2
PROCNO: 1

F2 - Acquisition Parameters
Date_: 20161216
Time: 12.09 h
INSTRUM: spect
PROBHD: z108618_0432 (4
PULPROG: udeft
TD: 17308
SOLVENT: CDCl3
NS: 96
DS: 0
SWH: 24038.461 Hz
FIDRES: 2.777728 Hz
AQ: 0.3600064 sec
RG: 203
DW: 20.600 usec
DE: 6.50 usec
TE: 300.0 K
D1: 4.0000000 sec
D12: 0.0000200 sec
D20: 200.0000000 sec
TD0: 1
SFO1: 100.6273568 MHz
NUC1: ¹³C
P1: 10.40 usec
P13: 2000.00 usec
P26: 500.00 usec
P1W1: 50.00299835 W
SPNAM[5]: Crp60comp.4
SPCAL5: 0.500
SPOFFS5: 0 Hz
SPW5: 8.26329994 W
SPNAM[9]: Crp60,0.5,20.1
SPOFFS6: 0.500
SPOFFS8: 0 Hz
SPW8: 8.26329994 W
SFO2: 400.1456006 MHz
NUC2: ¹H
CPDPRG[2]: waltz16
PCPD2: 90.00 usec
P1W2: 11.99499989 W
P1W12: 0.35578001 W

F2 - Processing parameters
SI: 131072
SF: 100.6162674 MHz
WDW: EM
SSB: 0
LB: 2.00 Hz
GB: 0
PC: 1.40



167.87

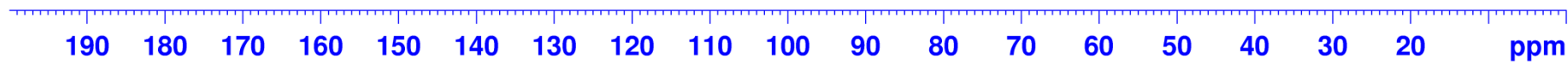
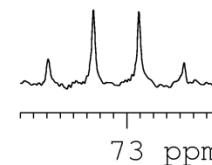
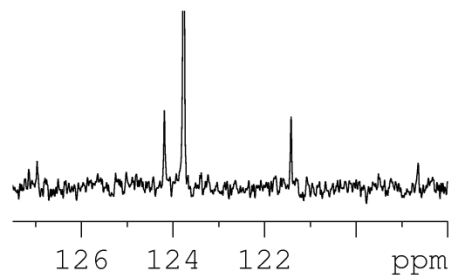
134.42
132.04
126.96
124.19
123.76
121.42
118.66

97.42

77.55
77.23
76.91
73.59
73.25
72.91
72.57

40.44

22.80





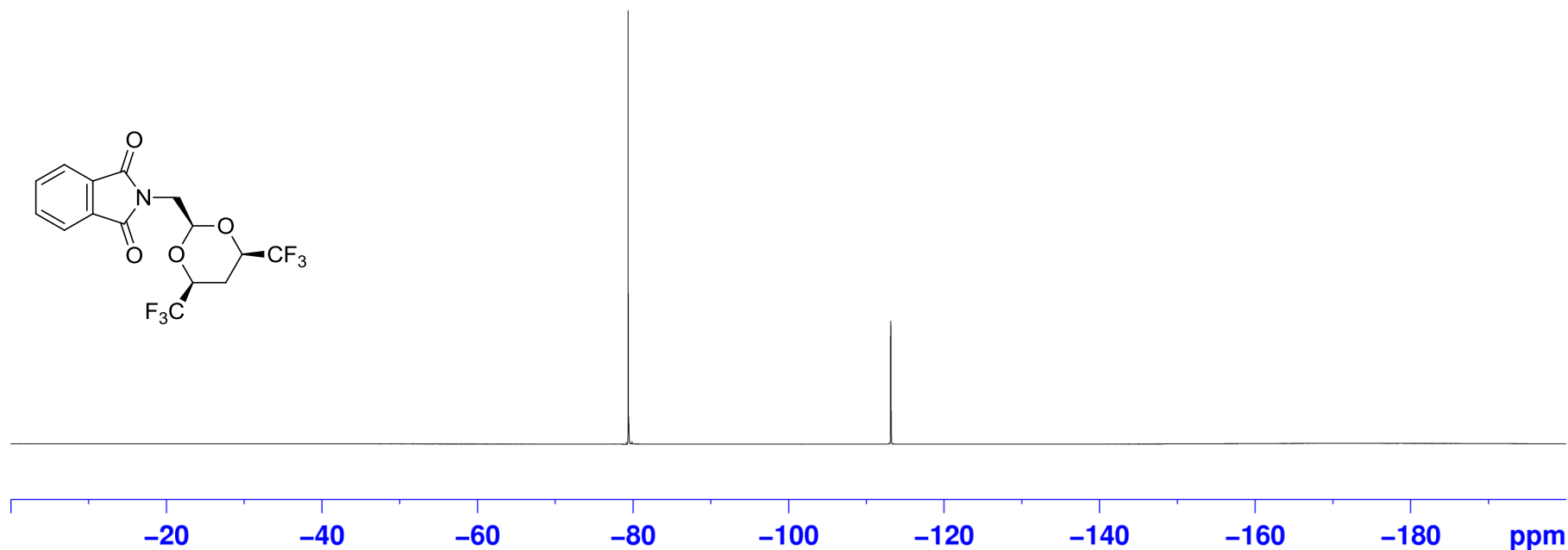
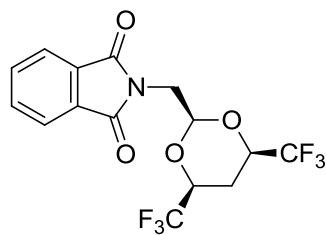
Current Data Parameters
NAME kl-3-29-f19-column2
EXPNO 3
PROCNO 1

F2 - Acquisition Parameters
Date_ 20161216
Time 12.13 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zgfhigqn.2
TD 131072
SOLVENT CDCl3
NS 5
DS 4
SWH 89285.711 Hz
FIDRES 1.362392 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 3.00000000 sec
D11 0.03000000 sec
D12 0.00002000 sec
TD0 1
SFO1 376.4738882 MHz
NUC1 19F
P1 11.05 usec
PLW1 17.98900032 W
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 11.99499989 W
PLW12 0.35578001 W

F2 - Processing parameters
SI 131072
SF 376.5115418 MHz
WDW EM
SSB 0
LB 2.00 Hz
GB 0
PC 1.00

— -79.38

— -113.15

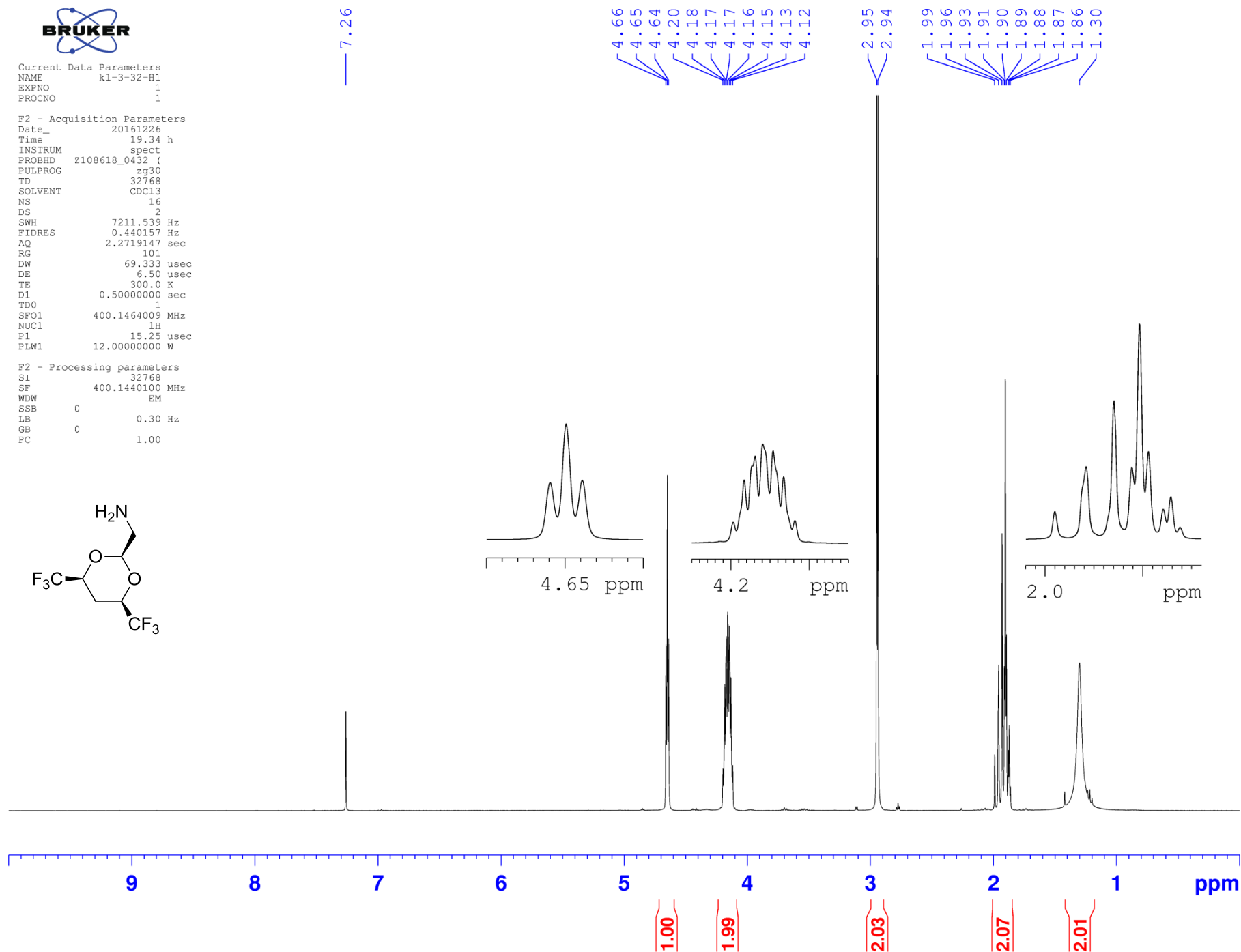
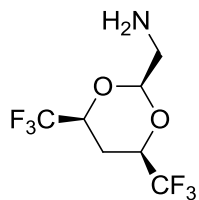




Current Data Parameters
NAME k1-3-32-H1
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20161226
Time 19.34 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zg30
TD 32768
SOLVENT CDCl3
NS 16
DS 2
SWH 7211.539 Hz
FIDRES 0.440157 Hz
AQ 2.2719147 sec
RG 101
DW 69.333 usec
DE 6.50 usec
TE 300.0 K
D1 0.50000000 sec
TD0 1
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 32768
SF 400.1440100 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

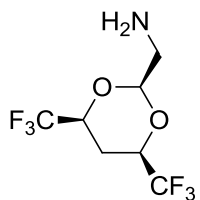




Current Data Parameters
NAME: K1-3-32-c13
EXPNO: 2
PROCNO: 1

F2 - Acquisition Parameters
Date_: 20161226
Time: 19.48 h
INSTRUM: spect
PROBHD: Z108618_0432 (4
PULPROG: udeft
TD: 17308
SOLVENT: CDCl3
NS: 96
DS: 0
SWH: 24038.461 Hz
FIDRES: 2.777728 Hz
AQ: 0.3600064 sec
RG: 203
DW: 20.600 usec
DE: 6.50 usec
TE: 300.0 K
D1: 4.00000000 sec
D12: 0.00002000 sec
D20: 200.00000000 sec
TD0: 1
SFO1: 100.6273568 MHz
NUC1: 13C
P1: 10.40 usec
P13: 2000.00 usec
P26: 500.00 usec
PLW1: 50.00299835 W
SPNAM[5]: Crp60comp.4
SFOAL5: 0 Hz
SPOFFS5: 0 Hz
SPW5: 8.26329994 W
SPNAM[9]: Crp60,0.5,20.1
SFOAL6: 0 Hz
SPOFFS6: 0 Hz
SPW6: 8.26329994 W
SFO2: 400.1456006 MHz
NUC2: 1H
CPDPRG[2]: waltz16
PCPD2: 90.00 usec
PLW2: 11.99499989 W
PLW12: 0.35578001 W

F2 - Processing parameters
SI: 131072
SF: 100.6162469 MHz
WDW: EM
SSB: 0
LB: 2.00 Hz
GB: 0
PC: 1.40



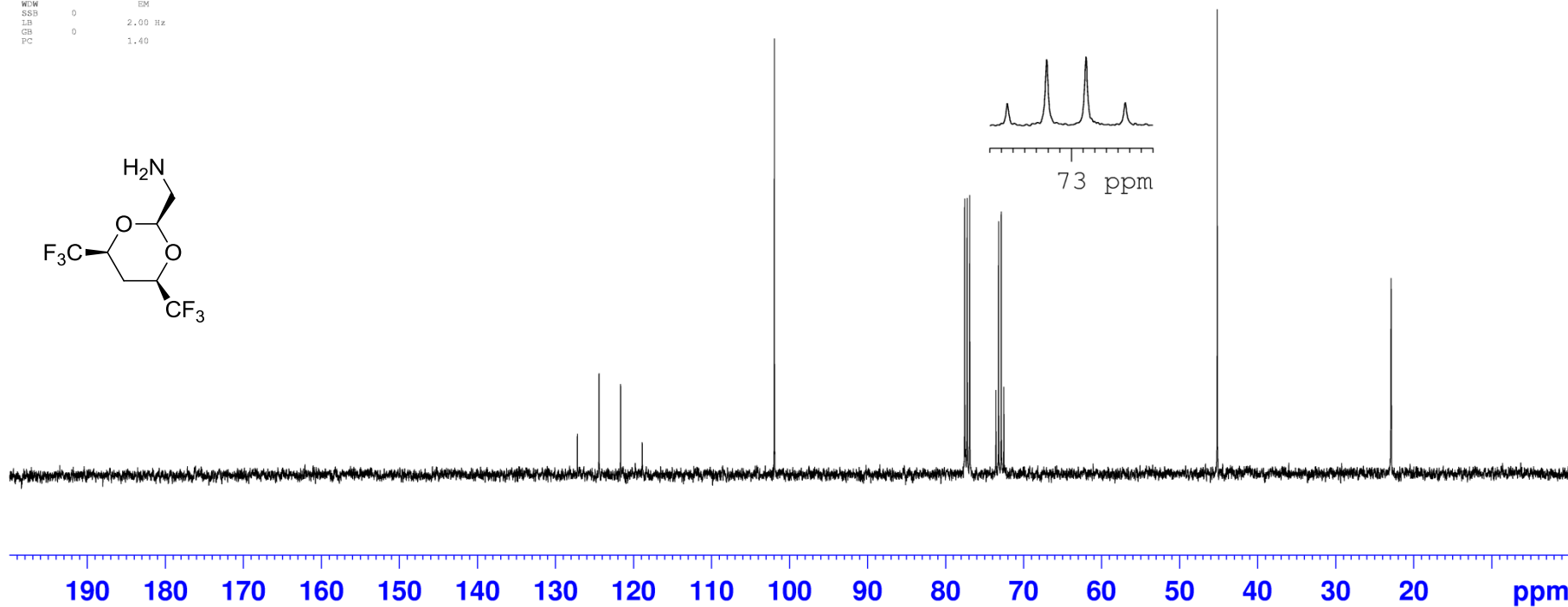
127.19
124.42
121.65
118.88

101.95

77.55
77.23
76.91
73.55
73.21
72.87
72.54

45.18

22.89

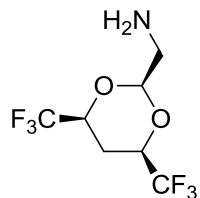




Current Data Parameters
NAME kl-3-32-F19
EXPNO 3
PROCNO 1

F2 - Acquisition Parameters
Date_ 20161226
Time 19.59 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zgfhgqn.2
TD 131072
SOLVENT CDCl3
NS 8
DS 4
SWH 89285.711 Hz
FIDRES 1.362392 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 3.00000000 sec
D11 0.03000000 sec
D12 0.00002000 sec
TD0 1
SFO1 376.4738882 MHz
NUC1 19F
P1 11.05 usec
PLW1 17.98900032 W
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 11.99499989 W
PLW12 0.35578001 W

F2 - Processing parameters
SI 131072
SF 376.5115622 MHz
WDW EM
SSB 0
LB 2.00 Hz
GB 0
PC 1.00



— -79.48

— -113.15

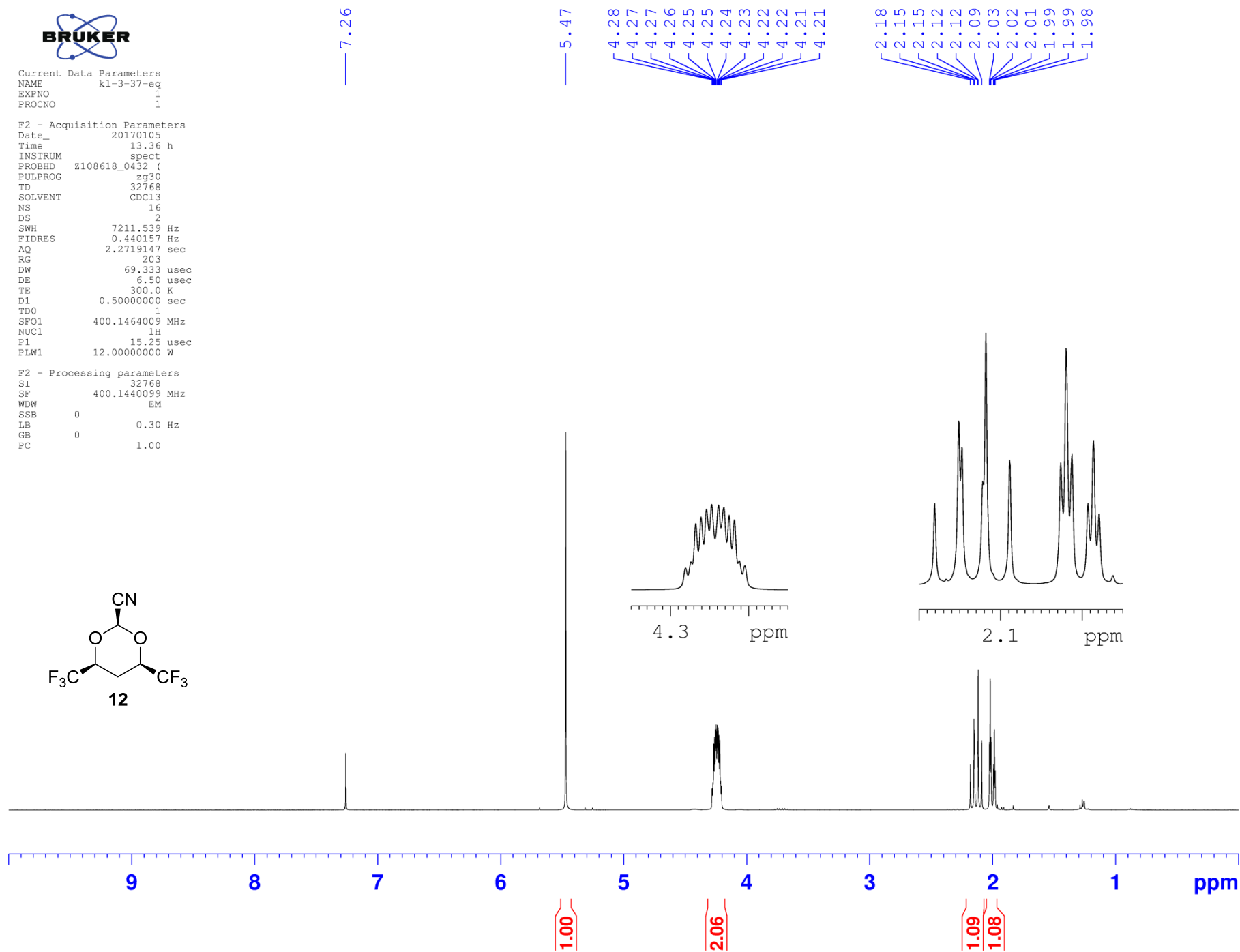
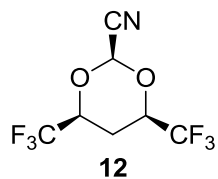




Current Data Parameters
NAME kl-3-37-eq
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20170105
Time 13.36 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zg30
TD 32768
SOLVENT CDCl3
NS 16
DS 2
SWH 7211.539 Hz
FIDRES 0.440157 Hz
AQ 2.2719147 sec
RG 203
DW 69.333 usec
DE 6.50 usec
TE 300.0 K
D1 0.50000000 sec
TD0 1
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 32768
SF 400.1440099 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

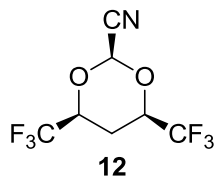




Current Data Parameters
NAME: k1-3-37-eq-c13
EXPNO: 1
PROCNO: 1

F2 - Acquisition Parameters
Date_: 20170105
Time: 13.50 h
INSTRUM: spect
PROBHD: Z108618_0432 (4
PULPROG: udeft
TD: 17308
SOLVENT: CDCl3
NS: 84
DS: 0
SWH: 24038.461 Hz
FIDRES: 2.777728 Hz
AQ: 0.3600064 sec
RG: 203
DW: 20.600 usec
DE: 6.50 usec
TE: 300.0 K
D1: 4.00000000 sec
D12: 0.00002000 sec
D20: 200.00000000 sec
TD0: 1
SFO1: 100.6273568 MHz
NUC1: 13C
P1: 10.40 usec
P13: 2000.00 usec
P26: 500.00 usec
PLW1: 50.00299835 W
SPNAM[5]: Crp60comp.4
SFOAL5: 0.500
SPOFF5: 0 Hz
SPW5: 8.26329994 W
SPNAM[9]: Crp60,0.5,20.1
SFOAL6: 0.500
SPOFF6: 0 Hz
SPW6: 8.26329994 W
SFO2: 400.1456006 MHz
NUC2: 1H
CPDPRG[2]: waltz16
PCPD2: 90.00 usec
PLW2: 11.99499989 W
PLW12: 0.35578001 W

F2 - Processing parameters
SI: 131072
SF: 100.6162667 MHz
WDW: EM
SSB: 0
LB: 2.00 Hz
GB: 0
PC: 1.40

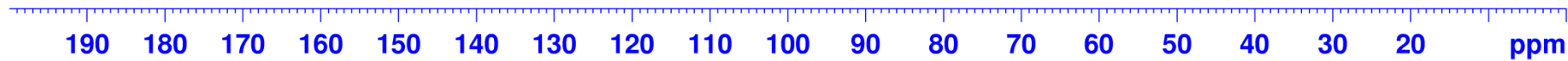
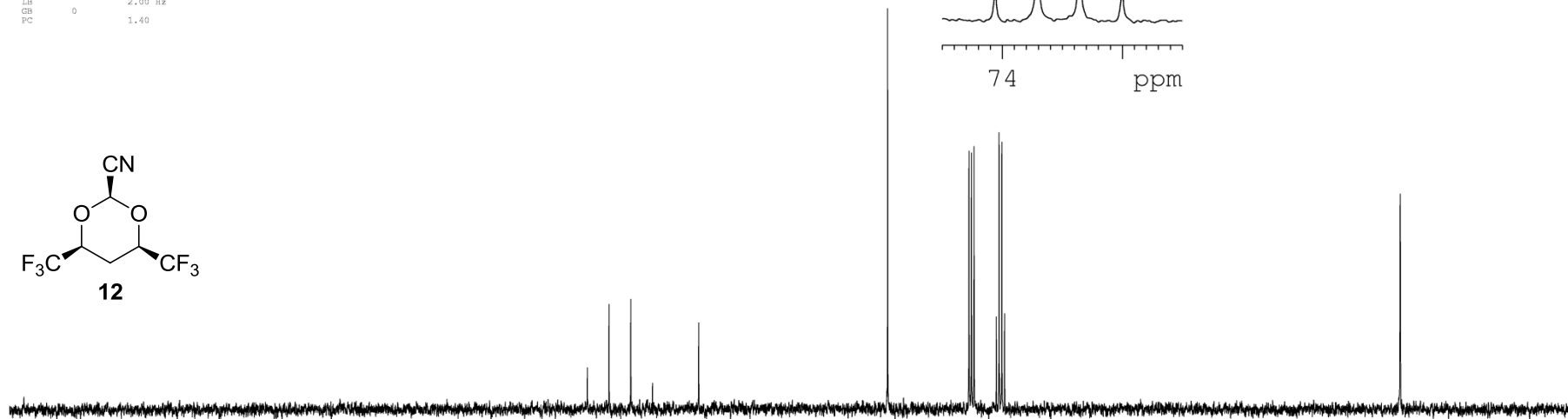
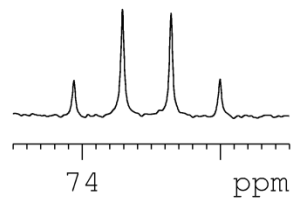


126.25
123.48
120.71
117.93
112.03

87.93

77.55
77.23
76.91
74.06
73.71
73.35
73.00

22.52

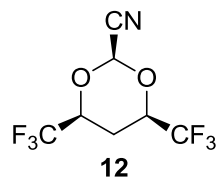




Current Data Parameters
NAME k1-3-37-eq-19F
EXPNO 2
PROCNO 1

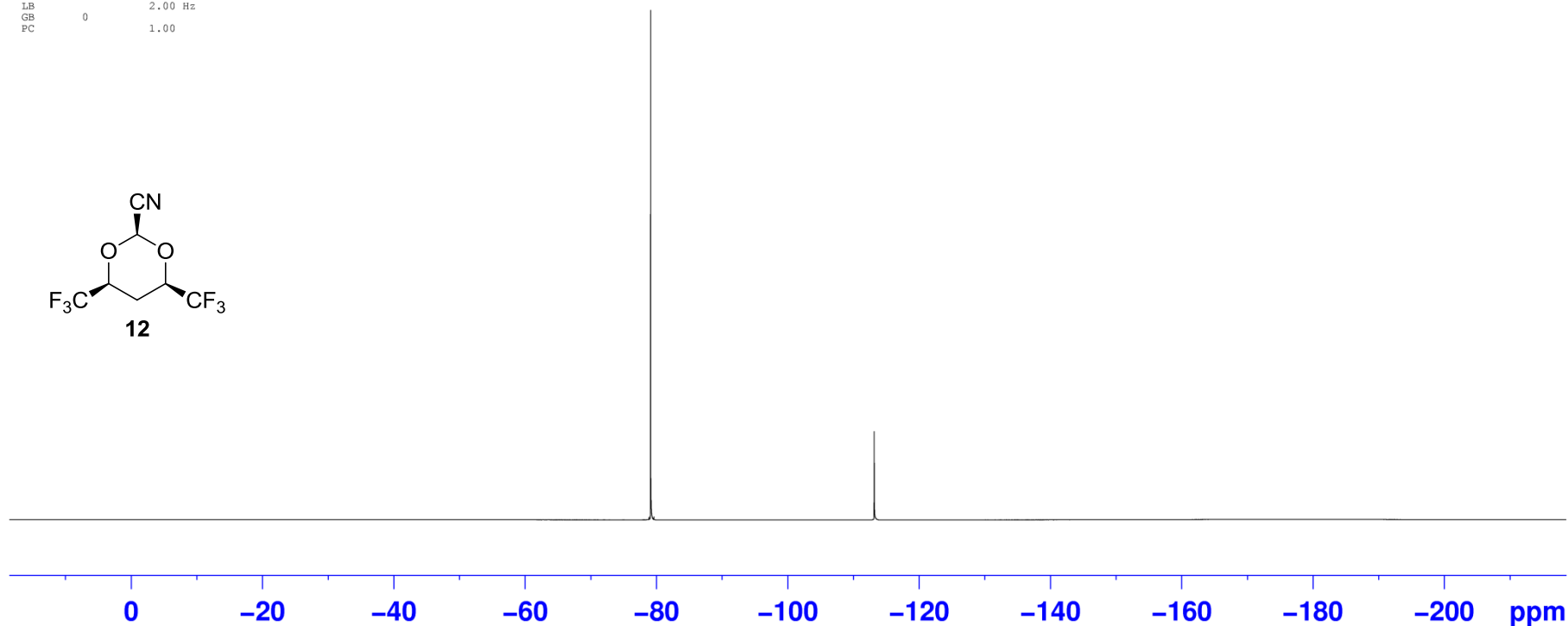
F2 - Acquisition Parameters
Date_ 20170105
Time 19.49 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zgfhgqn.2
TD 131072
SOLVENT CDCl3
NS 8
DS 4
SWH 89285.711 Hz
FIDRES 1.362392 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 3.00000000 sec
D11 0.03000000 sec
D12 0.00002000 sec
TD0 1
SFO1 376.4738882 MHz
NUC1 19F
P1 11.05 usec
PLW1 17.98900032 W
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 11.99499989 W
PLW12 0.35578001 W

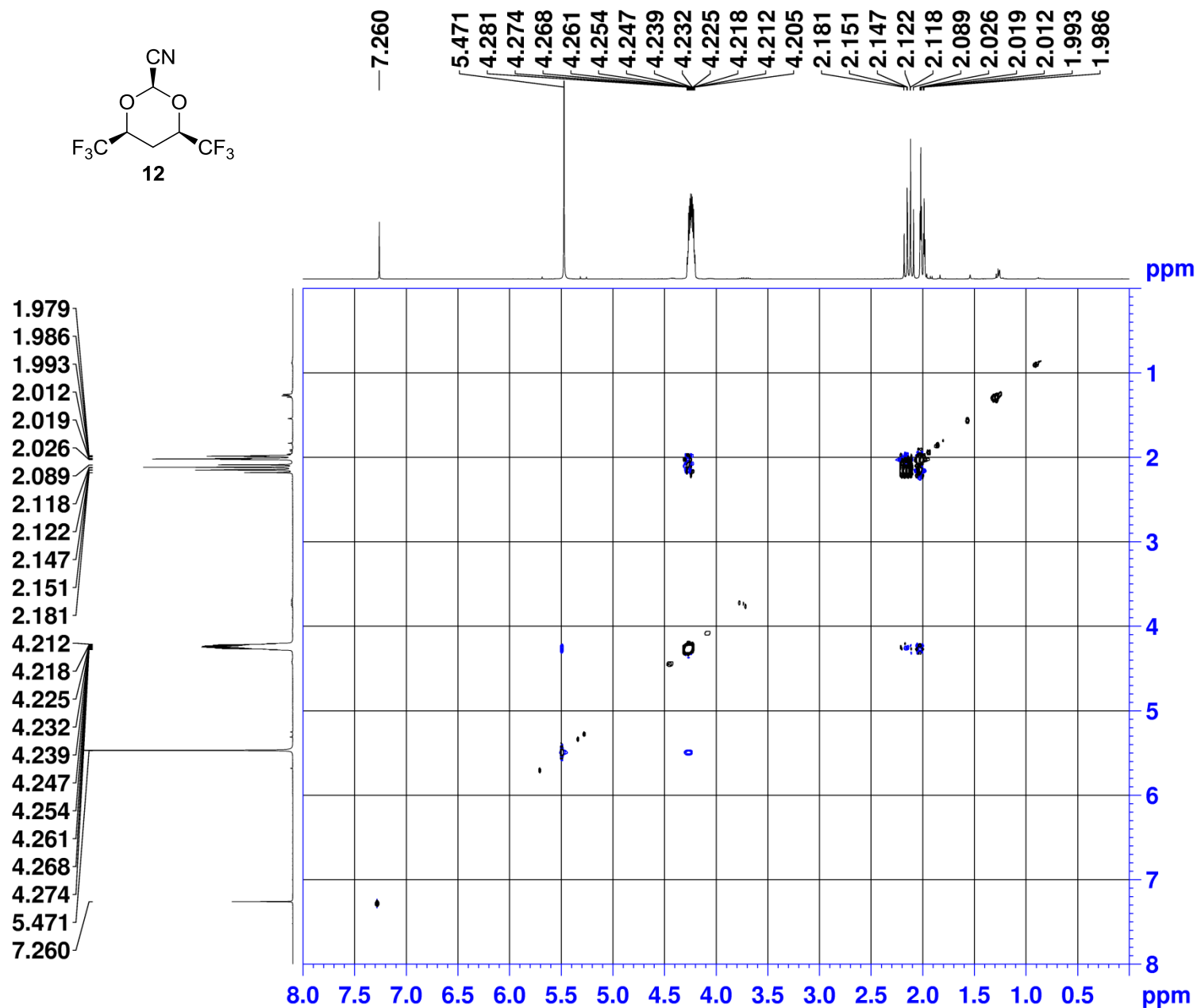
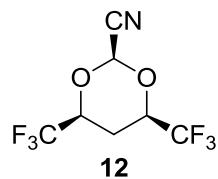
F2 - Processing parameters
SI 131072
SF 376.5115401 MHz
WDW EM
SSB 0
LB 2.00 Hz
GB 0
PC 1.00



— -79.11

— -113.15





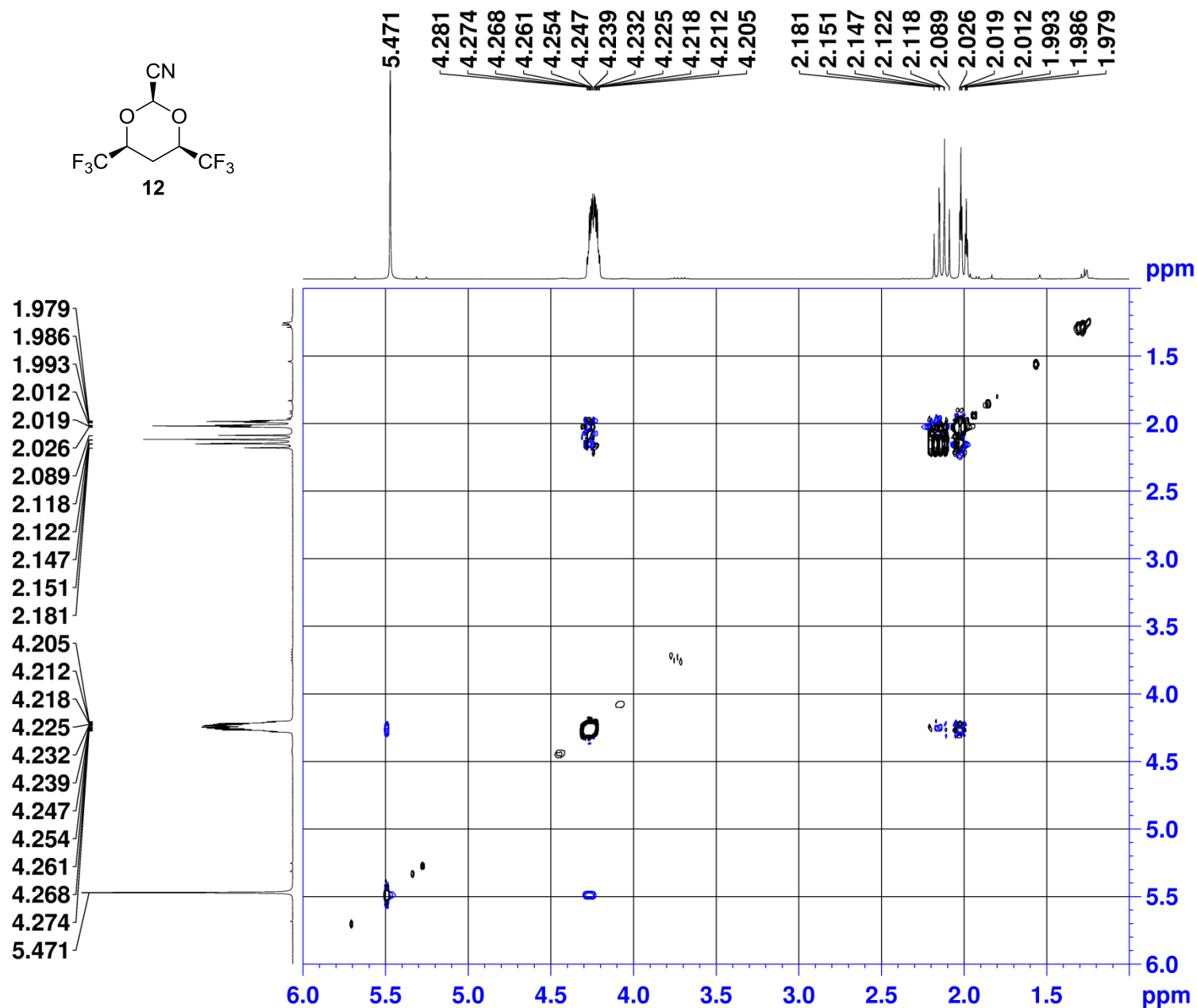
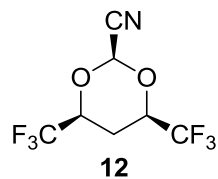
Current Data Parameters
NAME k1-3-37-eq-HNOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20170105
Time 18.50 h
INSTRUM spect
PROBHD Z108618_0432 (noesygpph)
PULPROG noesygpph
TD 2048
SOLVENT CDCl3
NS 4
DS 16
SWH 4084.967 Hz
FIDRES 3.989226 Hz
AQ 0.2506752 sec
RG 128
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010266 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec
TDav 1
SFO1 400.1458419 MHz
NUC1 1H
P1 15.50 usec
P2 31.00 usec
P17 2500.00 usec
PLW1 11.99499989 W
PLW10 4.26300001 W
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0



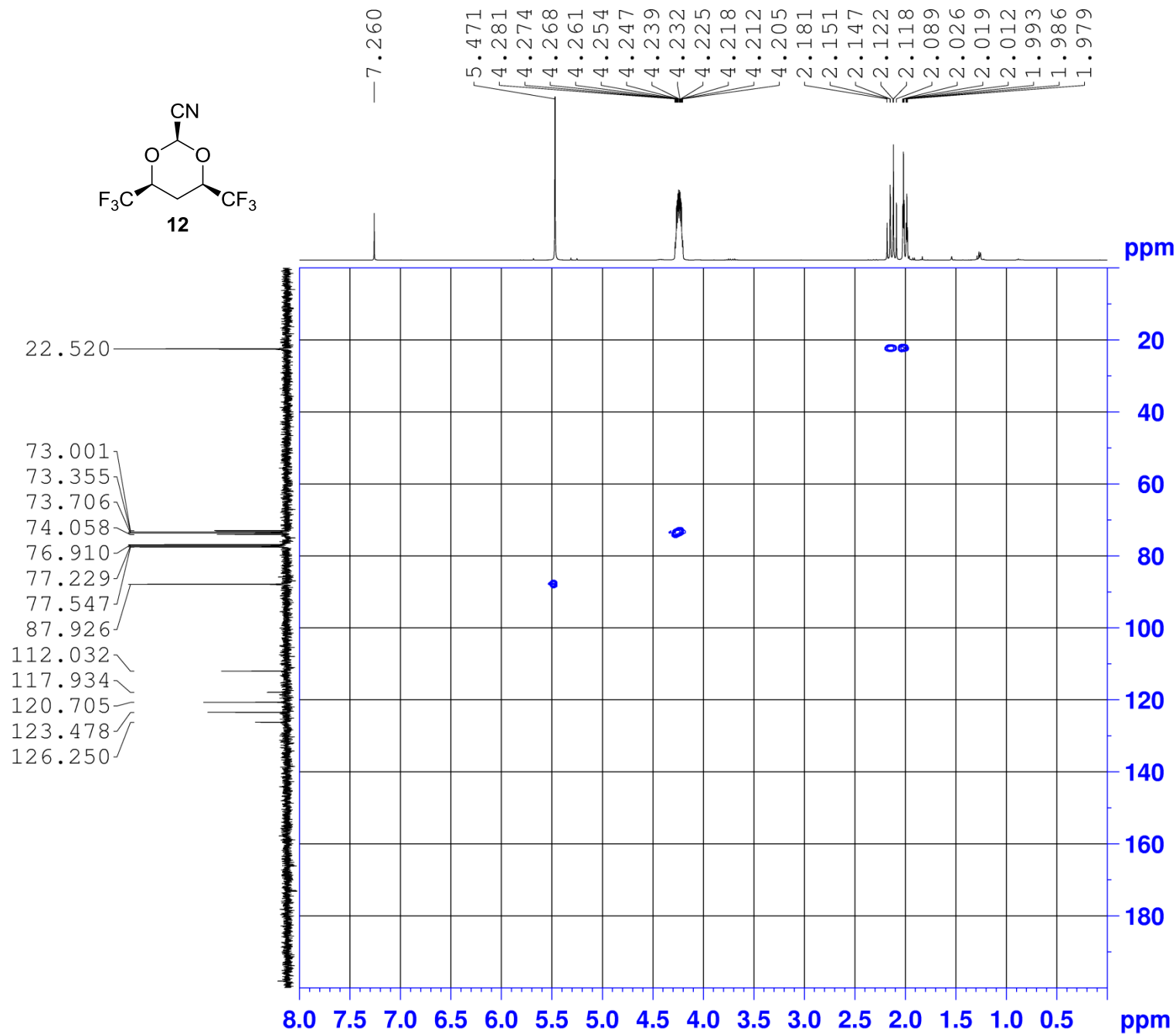
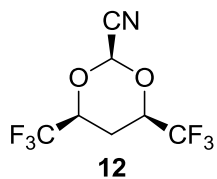
Current Data Parameters
 NAME k1-3-37-eq-HNOESY
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20170105
 Time 18.50 h
 INSTRUM spect
 PROBHD Z108618_0432 (
 PULPROG noesygpph
 TD 2048
 SOLVENT CDCl3
 NS 4
 DS 16
 SWH 4084.967 Hz
 FIDRES 3.989226 Hz
 AQ 0.2506752 sec
 RG 128
 DW 122.400 usec
 DE 6.50 usec
 TE 300.0 K
 D0 0.00010266 sec
 D1 2.00000000 sec
 D8 0.69999999 sec
 D11 0.03000000 sec
 D12 0.00020000 sec
 D16 0.00020000 sec
 IN0 0.00024480 sec
 TDAV 1
 SFO1 400.1458419 MHz
 NUC1 1H
 P1 15.50 usec
 P2 31.00 usec
 P17 2500.00 usec
 PLW1 11.99499989 W
 PLW10 4.26300001 W
 GPNAM[1] SMSQ10.100
 GPZ1 40.00 %
 P16 1000.00 usec

F1 - Acquisition parameters
 TD 256
 SFO1 400.1458 MHz
 FIDRES 15.956903 Hz
 SW 10.209 ppm
 FnmODE States-TPPI

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.00

F1 - Processing parameters
 SI 1024
 MC2 States-TPPI
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0



Current Data Parameters
 NAME kl-3-37-eq-RSQC
 EXPNO 1
 PROCNO 1

F2 - Acquisition Parameters
 Date_ 20170105
 Time 18.34 h
 INSTRUM spect
 PROSHD Z108618_0452 f
 PULPROG hsqcetgpa1sp2.3
 TD 1024
 SOLVENT CDCl3
 NS 4
 DS 16
 SWE 6410.256 Hz
 FIDRES 12.520032 Hz
 AQ 0.0798720 sec
 RG 203
 DW 78.000 usec
 DE 6.50 usec
 TE 300.0 K
 CNST2 145.000000
 CNST17 -0.500000

D0 0.0000300 sec
 D1 1.5000000 sec
 D4 0.00172414 sec
 D11 0.0300000 sec
 D16 0.0002000 sec
 D21 0.0036000 sec
 D24 0.0008900 sec
 IN0 0.0003010 sec
 TDev 1
 SFO1 400.1458807 MHz
 NUC1 1H
 P1 15.25 usec
 P2 30.50 usec
 P28 1000.00 usec
 PLW1 12.0000000 W
 SFO2 100.6233320 MHz
 NUC2 13C
 CPDPRG2 b1_psm4sp_4sp.2
 P3 10.00 usec
 P14 500.00 usec
 P24 2000.00 usec
 P31 1900.00 usec
 P63 1500.00 usec

PLW0 0 W
 PLW2 50.0000000 W
 PLW12 0.78125000 W
 SPNAM[3] Crp60,0.5,20.1
 SPOAL3 0.500
 SPOFFS3 0 Hz
 SPW3 7.63940001 W
 SPNAM[7] Crp60comp.4
 SPOAL7 0.500
 SPOFFS7 0 Hz
 SPW7 7.63940001 W
 SPNAM[14] Crp32,1.5,20.2
 SPOAL14 0.500
 SPOFFS14 0 Hz
 SPW14 3.25950003 W
 SPNAM[18] Crp60_xfilt.2
 SPOAL18 0.500
 SPOFFS18 0 Hz
 SPW18 1.83050001 W
 SPNAM[31] Crp32,1.5,20.2
 SPOAL31 0.500
 SPOFFS31 0 Hz
 SPW31 0.81497000 W

GPZ1 80.00 *
 GPNAM[2] SMSQ10.100
 GPZ2 20.10 *
 GPNAM[3] SMSQ10.100
 GPZ3 11.00 *
 GPNAM[4] SMSQ10.100
 GPZ4 -5.00 *
 P16 1000.00 usec
 P19 600.00 usec

F1 - Acquisition parameters
 TD 128
 SFO1 100.6233 MHz
 FIDRES 129.775742 Hz
 SW 165.084 ppm
 F2MODE Echo-Antiecho

F2 - Processing parameters
 SI 1024
 SF 400.1440000 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0
 PC 1.40

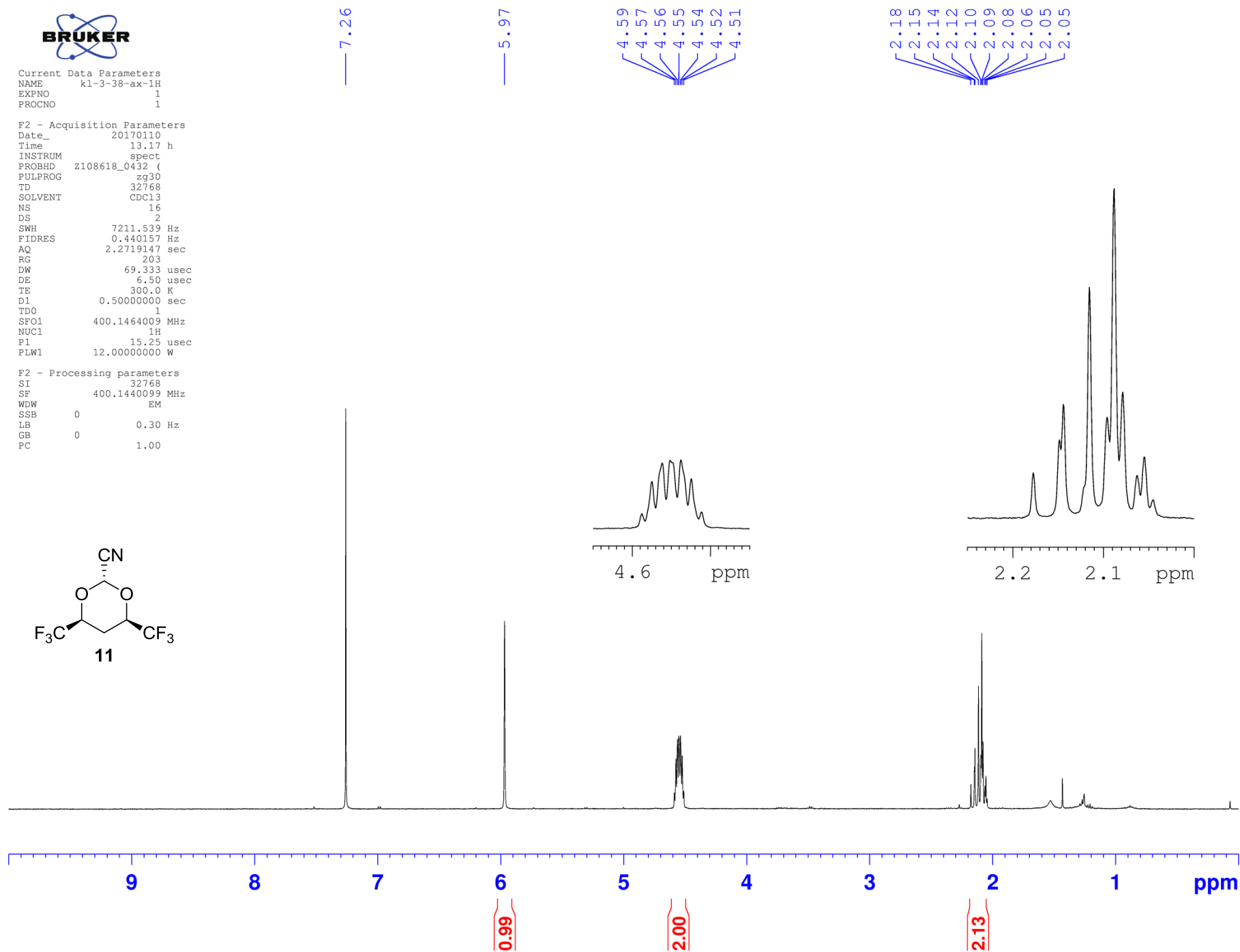
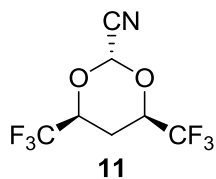
F1 - Processing parameters
 SI 1024
 MC2 echo-antiecho
 SF 100.6162890 MHz
 WDW QSINE
 SSB 2
 LB 0 Hz
 GB 0



Current Data Parameters
NAME kl-3-38-ax-1H
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20170110
Time 13.17 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zg30
TD 32768
SOLVENT CDCl3
NS 16
DS 2
SWH 7211.539 Hz
FIDRES 0.440157 Hz
AQ 2.2719147 sec
RG 203
DW 69.333 usec
DE 6.50 usec
TE 300.0 K
D1 0.50000000 sec
TD0 1
SFO1 400.1464009 MHz
NUC1 1H
P1 15.25 usec
PLW1 12.00000000 W

F2 - Processing parameters
SI 32768
SF 400.1440099 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

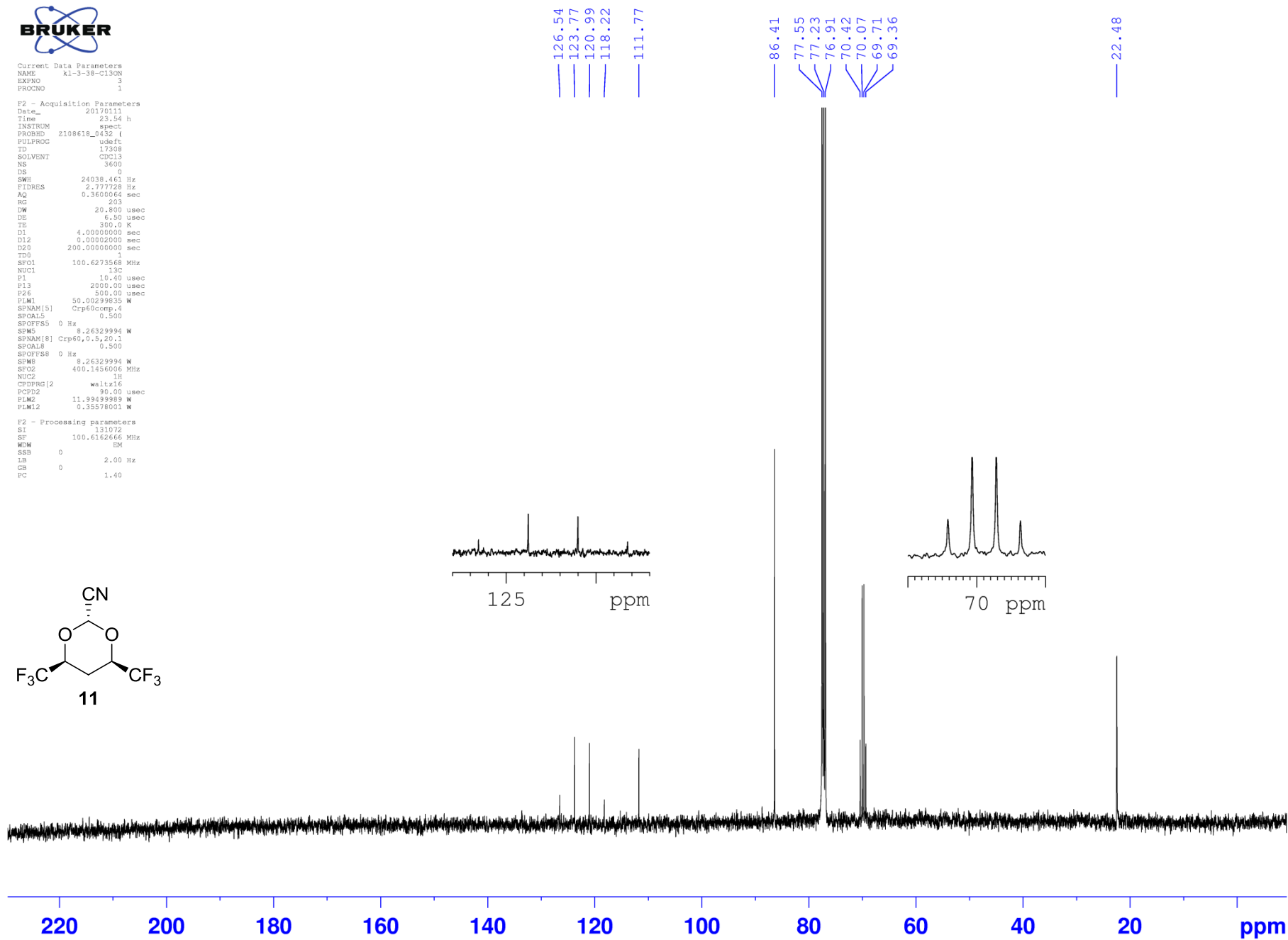
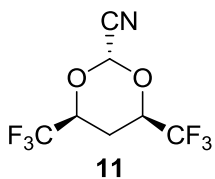




Current Data Parameters
NAME: k1-3-38-c13CN
EXPNO: 3
PROCNO: 1

F2 - Acquisition Parameters
Date_: 20170111
Time: 23.54 h
INSTRUM: spect
PROBHD: z108618_0432 (4
PULPROG: udeft
TD: 17308
SOLVENT: CDCl3
NS: 3600
DS: 0
SWH: 24038.461 Hz
FIDRES: 2.777728 Hz
AQ: 0.3600064 sec
RG: 203
DW: 20.600 usec
DE: 6.50 usec
TE: 300.0 K
D1: 4.00000000 sec
D12: 0.00002000 sec
D20: 200.00000000 sec
TD0: 1
SFO1: 100.6273568 MHz
NUC1: ¹³C
P1: 10.40 usec
P13: 2000.00 usec
P26: 500.00 usec
PLW1: 50.00299835 W
SPNAM[5]: Crp60comp.4
SFOAL5: 0 Hz
SPOFF5: 0 Hz
SPW5: 8.26329994 W
SPNAM[9]: Crp60,0.5,20.1
SFOAL6: 0 Hz
SPOFF6: 0 Hz
SPW6: 8.26329994 W
SFO2: 400.1456006 MHz
NUC2: ¹H
CPDPRG[2]: waltz16
PCPD2: 90.00 usec
PLW2: 11.99499989 W
PLW12: 0.35578001 W

F2 - Processing parameters
SI: 131072
SF: 100.6162466 MHz
WDW: EM
SSB: 0
LB: 2.00 Hz
GB: 0
PC: 1.40

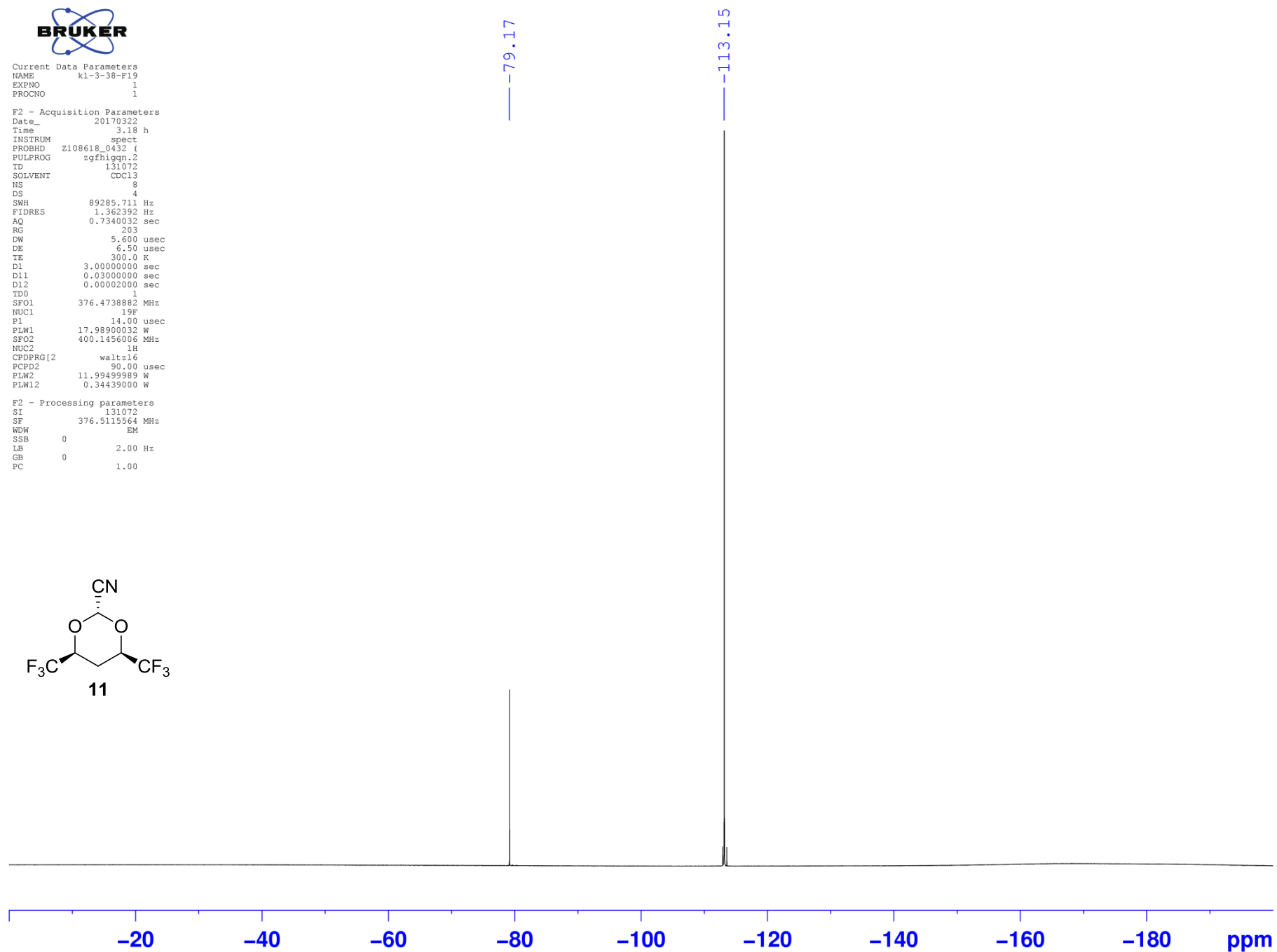
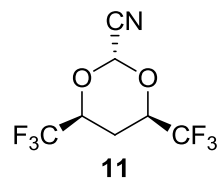


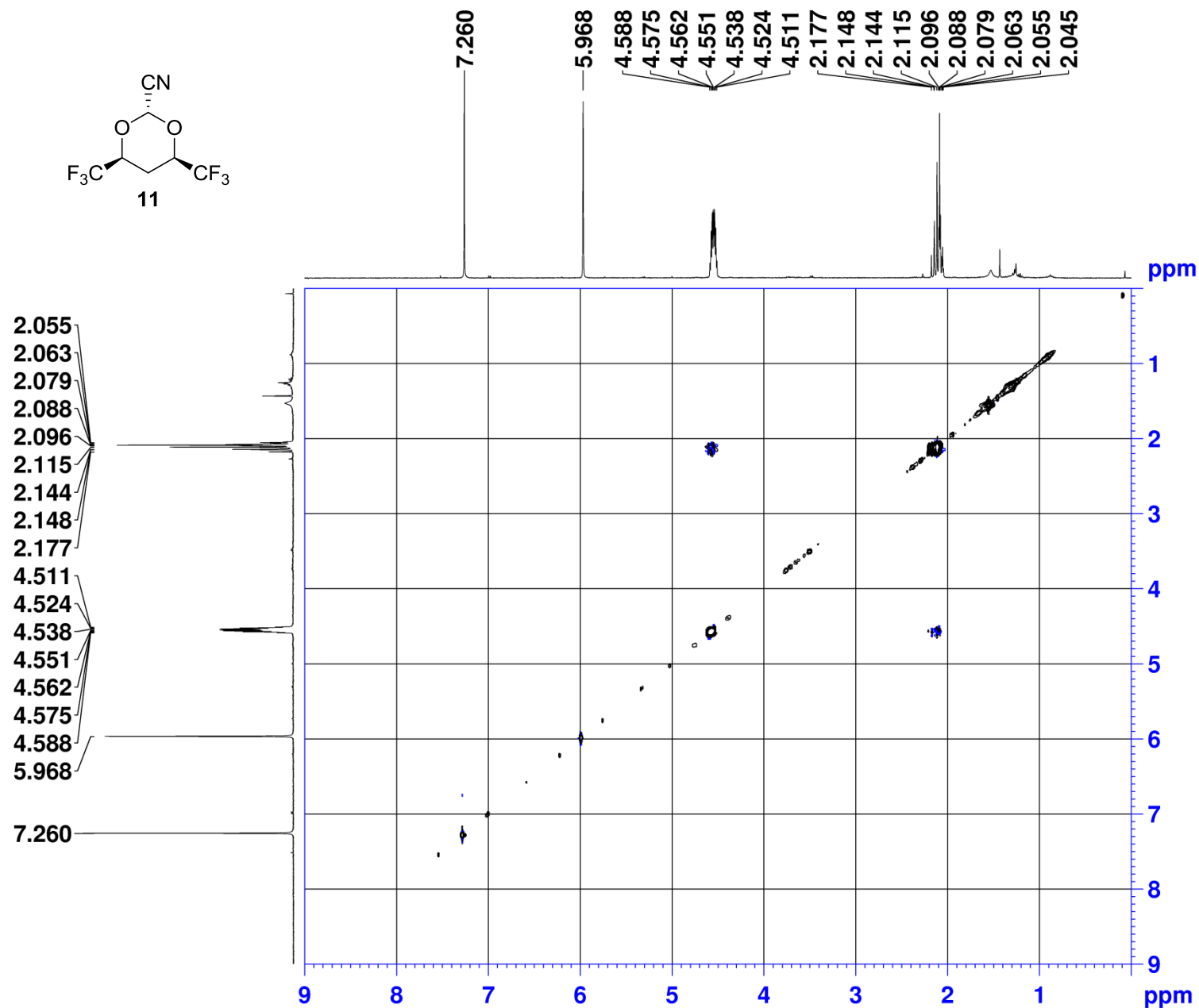
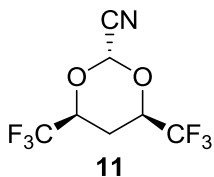


Current Data Parameters
NAME kl-3-38-F19
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20170322
Time 3.18 h
INSTRUM spect
PROBHD Z108618_0432 (
PULPROG zgfhgqn.2
TD 131072
SOLVENT CDCl3
NS 8
DS 4
SWH 89285.711 Hz
FIDRES 1.362392 Hz
AQ 0.7340032 sec
RG 203
DW 5.600 usec
DE 6.50 usec
TE 300.0 K
D1 3.00000000 sec
D11 0.03000000 sec
D12 0.00002000 sec
TD0 1
SFO1 376.4738882 MHz
NUC1 19F
P1 14.00 usec
PLW1 17.98900032 W
SFO2 400.1456006 MHz
NUC2 1H
CPDPRG2 waltz16
PCPD2 90.00 usec
PLW2 11.99499989 W
PLW12 0.34439000 W

F2 - Processing parameters
SI 131072
SF 376.5115564 MHz
WDW EM
SSB 0
LB 2.00 Hz
GB 0
PC 1.00





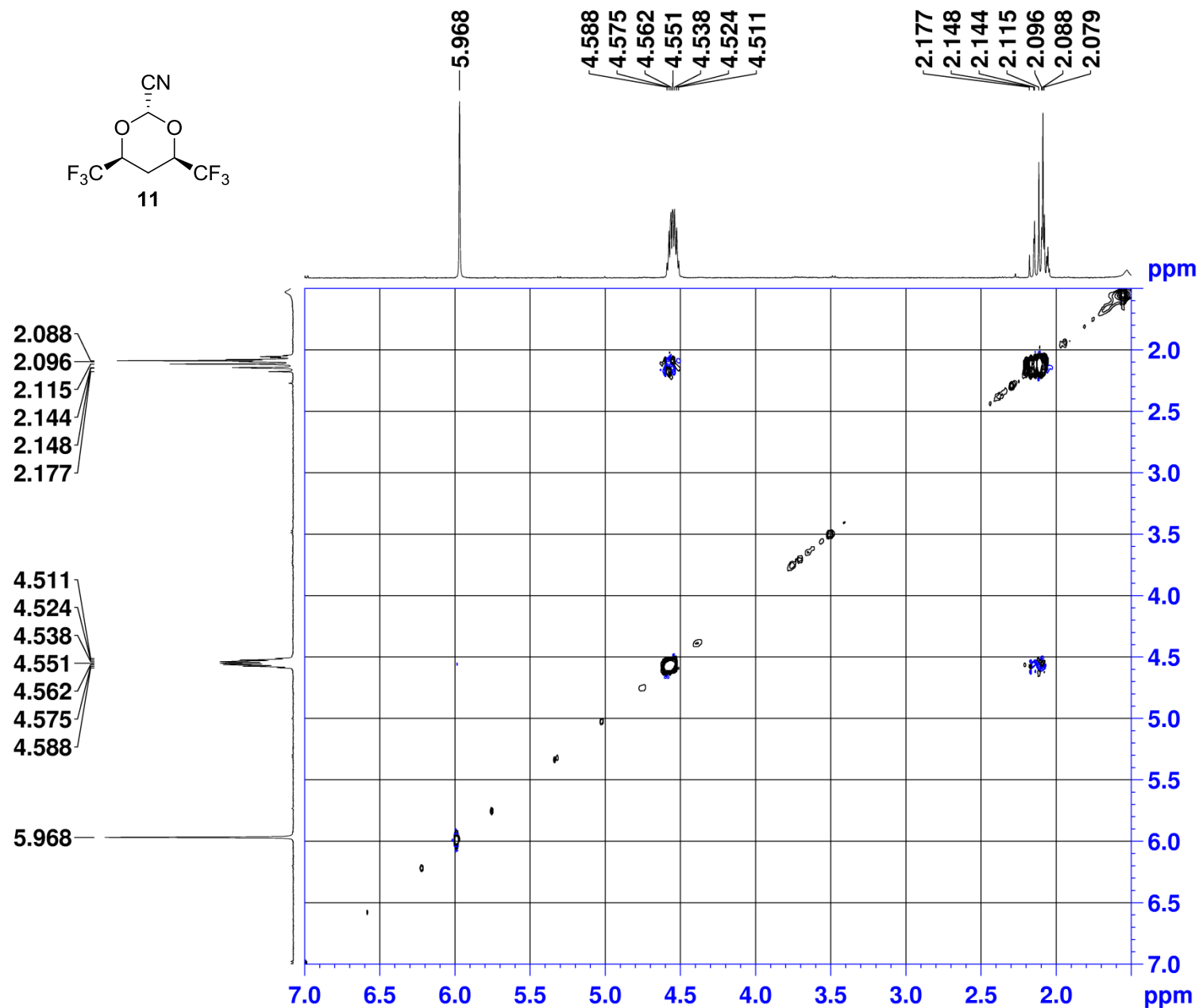
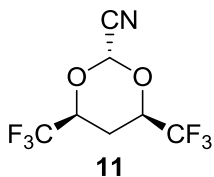
Current Data Parameters
NAME kl-3-38-HNOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20170111
Time 23.57 h
INSTRUM spect
PROBHD Z108618_0432 (noesygpph)
PULPROG noesygpph
TD 2048
SOLVENT CDC13
NS 4
DS 16
SWH 4084.967 Hz
FIDRES 3.989226 Hz
AQ 0.2506752 sec
RG 203
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010266 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00002000 sec
IN0 0.00024480 sec
TDav 1
SFO1 400.1458419 MHz
NUC1 1H
P1 15.50 usec
P2 31.00 usec
P17 2500.00 usec
PLW1 11.99499989 W
PLW10 4.26300001 W
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0



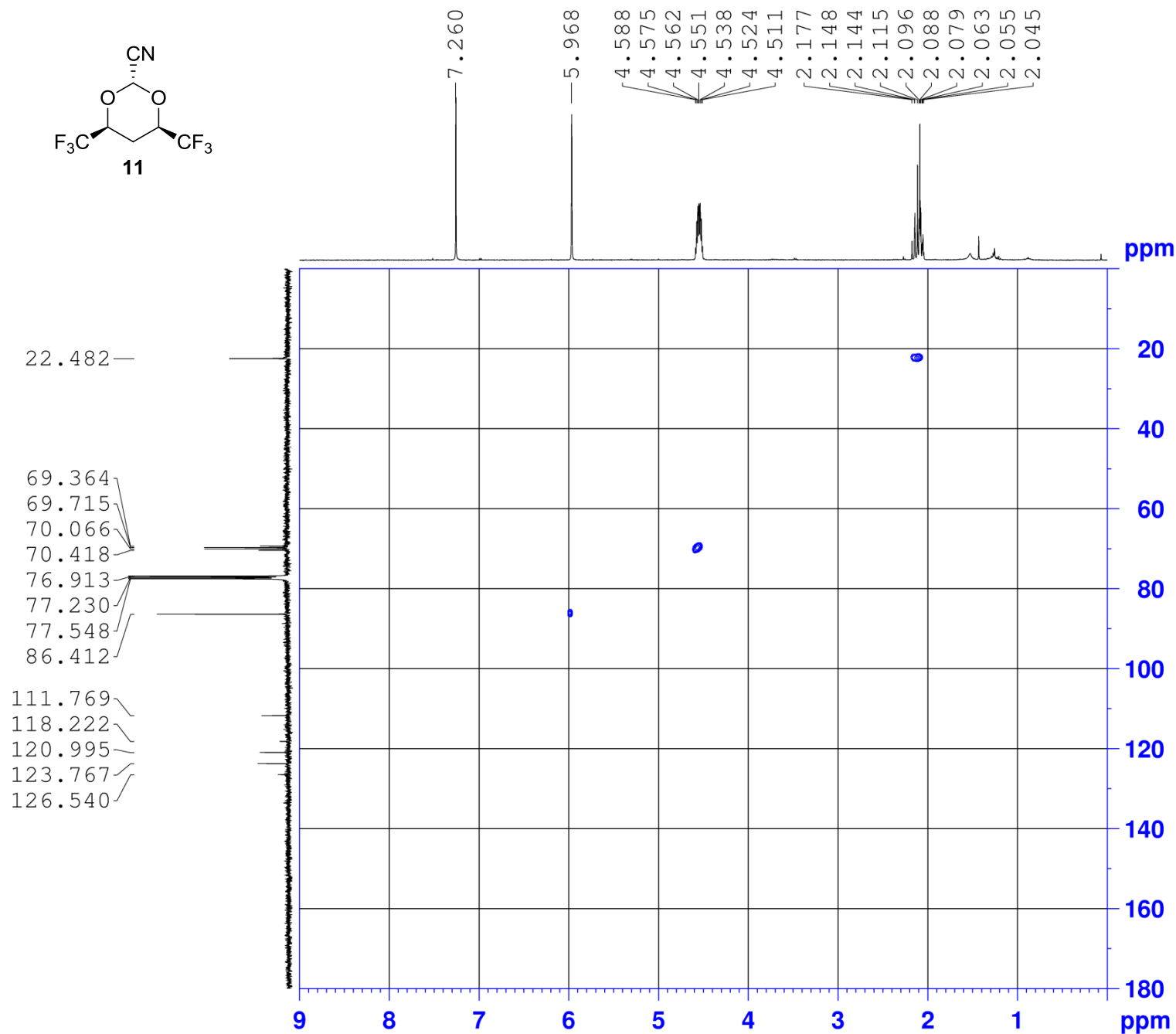
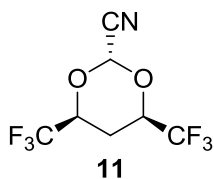
Current Data Parameters
NAME kl-3-38-HNOESY
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20170111
Time 23.57 h
INSTRUM spect
PROBHD Z108618_0432 (noesygpph)
PULPROG noesygpph
TD 2048
SOLVENT CDC13
NS 16
DS 16
SWH 4084.967 Hz
FIDRES 3.989226 Hz
AQ 0.2506752 sec
RG 203
DW 122.400 usec
DE 6.50 usec
TE 300.0 K
D0 0.00010266 sec
D1 2.00000000 sec
D8 0.69999999 sec
D11 0.03000000 sec
D12 0.00002000 sec
D16 0.00020000 sec
IN0 0.00024480 sec
TDAV 1
SFO1 400.1458419 MHz
NUC1 1H
P1 15.50 usec
P2 31.00 usec
P17 2500.00 usec
PLW1 11.99499989 W
PLW10 4.26300001 W
GPNAM[1] SMSQ10.100
GPZ1 40.00 %
P16 1000.00 usec

F1 - Acquisition parameters
TD 256
SFO1 400.1458 MHz
FIDRES 15.956903 Hz
SW 10.209 ppm
FnMODE States-TPPI

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSI
SSB 2
LB 0 Hz
GB 0
PC 1.00

F1 - Processing parameters
SI 1024
MC2 States-TPPI
SF 400.1440000 MHz
WDW QSI
SSB 2
LB 0 Hz
GB 0



Current Data Parameters
NAME kl-3-38-ax-RSQC
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20170110
Time 13.33 h
INSTRUM spect
PROBHD Z108618-0452 (4
PULPROG hsqcetgpa1sp2.3
TD 1024
SOLVENT CDCl3
NS 4
DS 16
SWH 6410.256 Hz
FIDRES 12.520032 Hz
AQ 0.0798720 sec
RG 203
DM 78.000 usec
DE 6.50 usec
TE 300.1 K
CNS12 145.0000000
CNS17 -0.5000000
D0 0.00000300 sec
D1 1.50000000 sec
D4 0.00172414 sec
D11 0.03000000 sec
D16 0.00020000 sec
D21 0.00360000 sec
D24 0.00089000 sec
INO 0.00003010 sec
TDav 1
SFO1 400.1458807 MHz
NUC1 1H
P1 15.25 usec
P2 30.50 usec
P28 1000.00 usec
PLW1 12.00000000 W
SFO2 100.6233320 MHz
NUC2 13C
CPDPRG2 bl_psm4sp_4sp.2
P3 10.00 usec
P14 500.00 usec
P24 2000.00 usec
P31 1900.00 usec
P63 1500.00 usec
PLW0 0 W
PLW2 50.00000000 W
PLW12 0.78125000 W
SPNAM[3] Crp60,0.5,20.1
SPOAL3 0.500
SPOFFS3 0 Hz
SPW3 7.63940001 W
SPNAM[7] Crp60comp.4
SPOAL7 0.500
SPOFFS7 0 Hz
SPW7 7.63940001 W
SPNAM[14] Crp32,1.5,20.2
SPOAL14 0.500
SPOFFS14 0 Hz
SPW14 3.25950003 W
SPNAM[18] Crp60_xfilt.2
SPOAL18 0.500
SPOFFS18 0 Hz
SPW18 1.83050001 W
SPNAM[31] Crp32,1.5,20.2
SPOAL31 0.500
SPOFFS31 0 Hz
SPW31 0.81497000 W
GPNAM[1] SMSQ10.100
GPZ1 80.00 %
GPNAM[2] SMSQ10.100
GPZ2 20.10 %
GPNAM[3] SMSQ10.100
GPZ3 11.00 %
GPNAM[4] SMSQ10.100
GPZ4 -5.00 %
P16 1000.00 usec
P19 600.00 usec

F1 - Acquisition parameters
TD 128
SFO1 100.6233 MHz
FIDRES 129.775742 Hz
SW 165.084 ppm
F2MODE Echo-Antiecho

F2 - Processing parameters
SI 1024
SF 400.1440000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40

F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6162890 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0